

THESIS

THE DEVELOPMENT OF KINETIC SCULPTURE BY THE
UTILIZATION OF SOLAR ENERGY

by

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DECLARATION

The work presented in this thesis was carried out by the author in the studios of the School of Fine Art/Sculpture and the laboratories of the School of Chemistry and the School of Physics at Leicester Polytechnic. This work took place between July 1975 and September 1978. None of the work has been submitted for any other degree or qualification; neither has the author been a registered candidate for any other degree or award during this period.

A handwritten signature in cursive script, reading "A. C. Stanger".

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ABSTRACT

A. A. Stonyer

The Development of Kinetic Sculpture by the Utilization of Solar Energy.

We have lost the close association that man enjoyed with the sun. This project is concerned with the development of kinetic sculpture in which movement is a response to the light and heat from the sun. After surveying a wide range of solar responsive devices and mechanisms, it became clear that a deliberate selection had to be made, consequently the basis of selection had to be decided. This involved three areas, chemical and mechanical as a response to temperature, and photoelectrical as a response to sunlight. These investigations led initially to the construction of maquettes, and one full size temperature sensitive sculpture; all of which were developed by reference to actual and predicted climatic conditions. In the sculpture, a cause and effect sequence emerged in which fluctuations in solar radiation (the cause) are responded to by kinetic movement (the effect). Further investigations dealt with the integration of the chemical, mechanical and photoelectrical areas. This resulted in the construction of maquettes, control mechanisms and a temperature sensitive kinetic sound sculpture. Finally, research was concerned with a refinement of the cause and effect sequence, through the development of a fully integrated technical and aesthetic interaction. A series of maquettes were subsequently produced, in which patterns of kinetic movement express the existence of states of wholeness between the sun and the technology.

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Introduction to Subject

0.1.1. This project is concerned with the development of kinetic sculpture which uses the light and heat from the sun. The direction this development has taken has been influenced by many factors connected with man's response to the sun and to the phenomena of movement. It is the intention in this chapter, to acquaint the reader with this range of factors.

0.1.2. The sun is a mass of gas with a diameter one hundred times that of the earth and an effective temperature of $6,000^{\circ}\text{C}$. It is the nearest star to earth, being eight light minutes, or 93,000,000 miles away. Reliable estimates conclude that 4,000,000 tons of solar matter are converted each second into radiation. Only a fraction of one percent reaches the planets; the rest is dissipated in space. Yet the total power from sunlight at the earth's surface is 110,000,000 kilowatts. ⁽¹⁾

0.1.3. Research, much of it undertaken this century, suggests that the ancients were deeply involved in charting the relationship between their environment, the sun, and what they knew of the solar system. ⁽²⁾ Sometimes this chart became a solar and lunar observatory, consisting of various three-dimensional configurations, from which the equinoxes and solstices, and subsequently the seasons, could be fixed. For instance, midsummer's day at Stonehenge is the time of year when the sun rises almost directly above the Heel stone, the latter being positioned midway between what were an avenue of chalk banks. It has been suggested that as knowledge grew such observatories, particularly Stonehenge, were developed to the extent that man could calculate the time of an eclipse. ⁽³⁾

0.1.4. In addition to the construction of solar observatories, man began the performance of periodic rites and rituals; these denoted and were sometimes thought to regulate the seasons. ⁽⁴⁾ In Europe these rituals were a compound of rites, involving music and dance, to which the inhabitants of the district, town or village,

contributed. In these rituals, patterns of imagery and movement were employed which bore a direct relationship to the climatic expectations of the seasons. ⁽⁵⁾ As far as this thesis is concerned their importance must be emphasised. Such rituals are examples of an interaction between art and science, to which kinetic art might be considered something of a successor.

0.1.5. At midwinter, when the hours of daylight are at a minimum and the warmth from the sun at its weakest and life seems at a standstill, the ancients went through the rituals of lighting bonfires. In addition to the bonfires they also decorated their buildings with evergreens. This was all done in the belief that the sun, enheartened by the imitative fire, would cause the north pole to commence its swing towards the sun. It was also hoped that the life of the buried seed would be assured by the ritual use of branches of evergreen. ⁽⁶⁾

0.1.6. In Thuringen in Saxony a spring ceremony was performed in which a straw figure, signifying death (winter), was thrown into the river. In Transylvania it was the custom for girls to go to church in black on the first day of Spring. On their exit from church they walked past a straw puppet. This completed, the puppet was drowned (end of death) and the girls dressed up in white (resurrection). ⁽⁷⁾ This latter theme of death and resurrection was taken up by the early Christians and given the religious significance of Easter. ⁽⁸⁾

0.1.7. The midwinter festival was a festival of hope, since it denoted the time in the year when the sun would gradually commence its movement spring-ward. Paradoxically, midsummer day, the longest day between sunrise and sunset, and the day upon which one's shadow at noon is the shortest it can be, was the festival of dread. On that day autumn appears on the skyline, a season which tokens a diminishing sun and a cold diminishing day. ⁽⁶⁾

0.1.8. Almost certainly, the knowledge that cycles such as solstices, equinoxes and seasons, are a recurring theme of this

planet ⁽⁹⁾ (just as breathing and the heart beating are a recurrent feature of bodily life) reassured man about the state of an otherwise hostile environment. Through this knowledge there developed an organic wholeness between man and nature, in which man was able to synchronise his agricultural activity with the climate. ⁽¹⁰⁾

0.1.9. The recognition of recurrence as a theme, leads inevitably to the concept of periodicity. Periodicity is fundamental to our notion of time, since it recognises the constancy of a series of recurring events. To the ancients these were days, years and significant stages in the year's cycle such as equinoxes and solstices. To modern man periodicity is reckoned not only in days, but in hours, minutes, seconds and micro seconds.

0.1.10. Sundials or shadow clocks, were first constructed around 3,500 B.C. ⁽¹¹⁾ They consisted of a gnomon, the shadow of which was observed as it moved from West to East. Early sundials seem to have been constructed more as temples for sun worship than as devices for telling the time of day. ⁽¹²⁾ Almost certainly the great ninety seven foot obelisk at Karnak in Egypt (approximately 1470 B.C.) was built primarily as a place where the sun's moving shadow could be worshipped. ⁽¹³⁾

0.1.11. By the 8th Century B.C. devices were in use which were used for telling the time of day. By this stage the Egyptians had learned that the most reliable way to tell the time of day by the sun was by the position of the sun's shadow rather than its length. ⁽¹³⁾ One such device which uses the position of the sun's shadow, is an Egyptian shadow clock. ⁽¹⁴⁾ It consists of a flat base with a raised cross piece at one end. On the base is inscribed a scale of six divisions. The base is placed in an east-west direction with the east shadow of the cross piece at the east end at sunset. The shadow of the cross piece indicates the time of day on the base. Many of these shadow clocks are still in use in Egypt.

O.1.12. In the 3rd century B.C. the Babylonian priest-astronomer Berossus developed a hemispherical sundial. ⁽¹¹⁾ This consisted of a block of wood or stone into which was cut a hemispherical opening. At the centre of this opening was fixed a pointer or style. A bead, approximately three times the diameter of the section of the style was made to slide up and down this style. The path travelled by the shadow of the style was approximately an arc. Since the length and positions of these arcs varies according to the seasons, an appropriate number of arcs were inscribed on the internal surface of the hemisphere. Each arc is reckoned from sunrise to sunset and have twelve equal divisions. The bead was positioned on the style so that its shadow followed the appropriate arc for the time of year.

O.1.13. Naturally the length of a day when recorded in this way varies from season to season. This was compensated by the position and size of the arcs in such a way that each day consisted of twelve hours, known as temporary hours. Therefore summer hours were longer than winter hours. Consequently summer is characterised by time extension and winter by time compression. According to the Arab astronomer al Battani (A.D. 858-929) this type of sundial continued to be used in Muslim countries well into the 10th century. ⁽¹¹⁾

O.1.14. The geometrical prowess of the Greeks allowed them to make sundials of considerable complexity. Apollonius of Perga, 250 B.C. developed a hemicyclium by using a conic section surface on which hour lines were inscribed. ⁽¹¹⁾ This innovation apparently gave greater accuracy. Ptolemy used the analemma, ⁽¹¹⁾ a device that enabled shadows to be projected geometrically on to flat surfaces, the latter being inclined at various angles to the horizontal. In general the Greeks constructed instruments with either vertical, horizontal or inclined dials, indicating time in temporary hours. One of the most ambitious sundial projects the Greeks attempted was the octagonal Tower of Winds, in Athens. ⁽¹¹⁾ It was built in 100 B.C. and had eight sundials, each facing various cardinal points.

0.1.15. The Arabs, inspired by the geometry the Greeks had developed, increased the variety of designs, some of which included pocket sundials. In the 13th century Abu al-Hasan simplified the design process by using the principles of trigonometry. He is also accredited with the introduction of equal hours for use in astronomy. (11)

0.1.16. Knowledge of the development of sundials in Europe is sketchy. At first the day was divided into three, as in the Saxon morntide, noontide and eventide. In England in 700 A.D. the Venerable Bede drew up a table for telling the time of day by measuring one's own shadow. (15) This was stepped off with the feet "heel to toe", along the length of the shadow. Some 700 years later the method was still in use.

Chaucer writes in the Parson's Prologue, (16) in the Canterbury Tales:

'Foure of the klokke it was tho, as I gesse:
For eleven foot, or lifel more or lesse,
My shadwe was at thilke tyme, as there,
of swich feet as my lengthe parted were.'

0.1.17. Many medieval English churches carry what appear to be crude sundials cut or scratched into their walls. These utilize the better procedure of measuring the position, rather than the length, of the shadow to tell the time.

0.1.18. Plants can be considered as clocks, with biological mechanisms which keep in time with their natural environment. For instance, the so called 'sensitive plants' such as Mimosa, open their flowers before sunrise in order to be ready for the sun and to take full advantage of it. In some respects, plants celebrate specific times of the year and sometimes the day, by processes such as germination, flowering and seeding etc. In much the same way, man celebrated specific times of the year by ritual. Furthermore, a plant bursting into flower can be seen to be in the process of

releasing a wealth of potential visual energy. Likewise, people in the performance of some seasonal ritual may be in the process of releasing a whole range of potential audio-visual imagery.

0.1.19. In the formal gardens of 19th century Europe flower clocks provided an ingenious and decorative way of telling the time. ⁽¹⁷⁾

These clocks were a series of flower beds, which were often laid out in the form of a clockface. The beds were planted with flowers which were known to open and close at prescribed hours. In this way time could be determined to within half an hour.

0.1.20. It is not certain when the first mechanical clock was invented but existing examples date from 1250. ⁽¹⁸⁾ With the advent of the clock man no longer needed to mark daylight time according to a series of fluctuating periods. Instead, civilization could be mechanically conditioned through the regularity of hours and minutes which had a precise periodicity. This heralded the breakdown of the previously mentioned wholeness, (see paragraph 0.1.8.) which existed between man and nature. This led, particularly in urban settlements, to the regulation and synchronization of labour according to a set of time measurements which bear only the most tenuous relationship to the natural sun time. ⁽¹⁹⁾

0.1.21. The earliest clocks were made by armourers who at that time were the principle metal workers. ⁽¹⁸⁾ This accounts for the appearance of soldiers (Jacks) on clocks to strike bells etc. These examples of automata performed the task previously carried out hourly by the keeper of the clock.

0.1.22. The great Strasbourg cathedral clock which dates from 1352 stands as the most elaborate example of the early clockmakers skill. Machines such as this were to set the living pattern for entire vicinities, and were to play a central role in the development of the industrial revolution.

0.1.23. Clocks exhibited less military imagery as guilds of professional clock makers developed who were not principally concerned with the manufacture of armour. Subsequently, stages of life representing infancy, middle age, senility and death became important themes to use alongside the quantitative recording of the hands and dial of the clock.

0.1.24. By the sixteenth and seventeenth centuries clockmakers skills had developed to the point where clocks became planetary as well as local timekeepers. Clocks consequently incorporated astroblabes, astrological recorders, history indices and perpetual calendars. These were often accompanied by an allegorical world of automata. The automata usually consisted of figures representing various levels of theological and philosophical interpretation. (20) As a result of this display of the clockmakers skill, clocks by this time had become pre-programmed models of the solar system which depicted quantitatively (through dials) and qualitatively (through visual imagery, particularly automata) man's vision of a universe controlled by God.

0.2.1. Kinetic sculpture is sculpture which uses actual movement as one of its dimensions. The first well-recorded attempt at producing a kinetic sculpture occurred in 1920. (21) Movement in art has always been a vitally important consideration, but prior to this date it existed through the use of perceptual tensions. Movement in sculpture has often been implied by relating aspects of the form to the daily movement of the sun. It is not surprising that the interactive properties brought about by carefully considered combinations of light and form have been a central concern to artists and architects. As far as the ancients are concerned this has already been discussed in the opening paragraphs of this chapter.

0.2.2. Through my earlier work I became increasingly concerned with natural light and its ability to modulate and sometimes radically alter the quality of form, some five years before I commenced this research programme. I was fortunate enough to spend eighteen months of this period as a lecturer in the Faculty of Architecture at the Middle East Technical University, Ankara, Turkey. During these eighteen months I became particularly interested in Seljuk and early Ottoman architecture, especially in the way light becomes a form-defining device in these two movements.

0.2.3. On a visit to the Mevlana Mosque at Konya an aspect of the value of light as a fundamental ingredient in architecture and art was brilliantly demonstrated to me.

0.2.4. Natural light as used in this building, becomes a dynamic tool which has the capacity to define and redefine form, to the extent that at times the architectural space dissolves into a compound of reds, greens, blues and golds. This special atmospheric quality becomes, in fact, a dynamic microcosmic revelation of the macrocosmic environment outside.

0.2.5. Whilst on this visit I also saw the Whirling Dervishes perform (originally the Dervishes used to perform in the mosque; unfortunately, due to lack of space they now dance in a sports hall) and began to realise how much more profound these patterns of movement must have been when performed in the building for which they were designed.

0.2.6. As far as our European tradition is concerned, examples of works of art which have been conceived directly around the possibilities offered by natural light are many and varied. From antiquity a notable example is the Parthenon Freize which runs around the top of the outside of the temple-chamber and its two porches. This freize was screened by the upper part of the external colonnade; a factor which improved the freize's illumination. Since the freize was set immediately under the ceiling of the

colonnade it was lit almost wholly by reflected light from below. (22)

0.2.7. In both art and architecture the Gothic sculptors, architects and painters show a highly inspired understanding of the practical and metaphysical possibilities of light. Suger, the abbot of St. Denis, was partly responsible for the intellectual framework of this period and its development through architecture. He justified the practical and metaphysical aspects of light as an essential ingredient in ecclesiastical architecture, as follows.

Suger states,

"The noble work shines brightly, but the work which so shines should brighten all minds, that they may go through all true lights, to that true light where Christ is the door." (23)

0.2.8. The above statement receives its most profound realisation in the great cathedral at Chartres. There, the unity of interior space in combination with the possibilities offered by natural light, are masterfully demonstrated. Unity is achieved from the bases of the piers to the keystones, each single part of detail being related to another and combined into a magnificent whole. The continuous movement from the great piers and clustered shafts, heavenwards to the vaults high above, causes the spectator to be irresistably drawn to look up through the dimly lit arches to the light which pours in beneath the vaults from the great elevated windows.

0.2.9. Some three hundred years later the baroque sculptor Gian Lorenzo Bernini, 1598-1680, took up the idea of using natural light to accentuate the aesthetic and intensify the religious significance of his work. This he achieved by planning how the sun should light his sculptures at particular times of the day. (24) In so doing Bernini achieved a continually changing pattern of tonal values; these are essential to the vigour of his work. In his 'Ecstasy of

S. Theresa,' Bernini specified the colours of the stained glass in the surrounding windows. The sun's daily cycle is therefore charted by the changing colour of the sculpture. Highlights and shadows and combinations of colours flicker and dance about the work, to the extent that movement often seems real rather than implied.

0.2.10. J.M.W. Turner (1775-1851) and John Constable (1776-1837) were very concerned in their various special ways with the effects of natural light. Constable is best known for his landscapes, though much is now being made of the many nature studies which formed the background to these landscapes. Prior to Constable, clouds in painting were usually regarded as accidental effects. What Constable did was to dispel the idea of nature as a combination of accidental effects; instead he advocated a study of nature which was influenced by the scientific discoveries, and rationalist theories of the time. In a lecture to the Royal Institution, Constable defined his theory of painting as follows,

"Painting is a science, and should be pursued as an enquiry into the laws of nature." (25)

0.2.11. Constable assisted his enquiry into the laws of nature by his interest in meteorology and chromatology. This led to the systematic completion of a series of cloud studies based on faithfully observed visual phenomena. These studies, even by today's standards, are a reliable and detailed classification of meteorological phenomena; yet ultimately they represent a masterly fusion of nature and imagination.

0.2.12. Through these studies of meteorological states Constable brought to the fore a theme which has been near to the heart of many subsequent artists and art movements. This theme, to which kinetic sculpture is an obvious successor, involves the artist in an informed awareness of the branches of scientific knowledge which lie adjacent to the artist's own field. This takes into account either,

or in some cases both, the medium and the environment from which the artist consciously or subconsciously draws inspiration. In Constable's case, the medium (paint on canvas) was enriched by developments in chromatology; whilst his awareness of the external environment was deeply affected by his interest in meteorology.

0.2.13. For the greater part of Turner's life he was obsessed with an investigation of the nature of sunlight, whether glittering on the domes and canals of Venice, as in 'Festive Lagoon scene, Venice', of 1840 or shimmering hazily on the Thames, as in 'Sunrise with a Boat between Headlands' of 1835. From this investigation of sunlight effects, Turner developed a set of colour/light notes in which he explored the theme of colour equivalents for sensations.

0.2.14. Turner, rather more than Constable, was certainly interested in the imagery which the technology of the day offered. In this respect he can be accredited as the first artist to record the mood of the so called industrial revolution. His painting entitled, 'Rain, Steam and Speed', of 1843, masterfully catches the dynamism of a locomotive speeding through a storm. Light shines onto the locomotive and is reflected back, where it diffuses in the swirling rhythms of the storm. It is recorded that before painting this picture, Turner put his head out of the carriage window of a fast moving railway train during a storm. ⁽²⁶⁾ He considered it was not only necessary to see, but also to feel the sensation he wanted to put across in his picture.

0.2.15. In his last pictures of Venice, Petworth and Norham Castle, Turner retained only the slightest elements of the scene; a heightened alliance of thought, sensibility and imagination seems to have taken him over and caused him to produce sunlight as transitions of tones and films and mists of colour. On his death-bed he is said to have pronounced "The sun is God." ⁽²⁷⁾ In fact he died at ten o'clock on a dull and gloomy morning. But his physician recalled that just before nine, "the sun burst forth and shone direct on him with that brilliancy he loved to gaze on and

transfer the likeness to his pictures."

0.2.16. Turner's great contribution to painting was that he liberated light from being solely a means of recording three-dimensions. This opened the way to purely chromatic painting for which luminosity is a result of the degree and saturation of hues.

0.2.17. It became the task of artists on the continent to take up the developments of Constable and Turner. Impressionism was the derisive name given to the most important artistic phenomenon of the 19th century, and the first of the truly modern movements. The name was derived from a painting by Monet, entitled *Impressionism, Sunrise*, of 1872. This painting consists of the play of light on water and has the spectator looking straight into the rising sun.

0.2.18. One of the aims of Impressionism, as distinct from just producing 'an impression' was motivated by a desire to achieve an ever greater naturalism by attempting to render the play of light on the surface of objects by an exact analysis of tone and colour. This is particularly true of Monet, who devoted a considerable amount of time to the study of objects as lit by the sun at different times of the day. The most familiar examples are the series of paintings of the same haystack or the studies of the facade of Rouen Cathedral. In each case Monet was concerned with serialising the transformation of the object by the daily course of the sun.

0.2.19. Impressionist interest in light and colour was influenced by the researches into the physics of colour carried out by scientists such as Chevreul. Chevreul's researches conclude that an object of a given colour casts a shadow tinged with its complementary. This theory was further developed by Seurat, 1859-91, who evolved the theory of divisionism.

0.2.20. Meanwhile, the Frenchman, Andre Ampere with his essay on the 'Philosophy of Forces' and later the German, Franz Releaux with his theories on 'Pair Closure', ⁽²⁸⁾ showed visually, through a

series of schematic presentations, that the engineers process of working need not be a random trial and error affair. Instead the engineer could now develop with scientific thoroughness machines as efficient work advantage systems. The machine was now becoming the model for a well run society; man was now a tool of his tools.

0.2.21. At approximately the same time as Releaux was expounding his theories on pair closure and classical machines, the physiologist E.J. Marey and the photographer E. Muybridge (both born in 1830), were producing photographs which gave a clear record of human and animal motions. These photographs were presented as series of successive images which captured the trajectories of birds in flight, horses galloping and humans descending stairs. This work culminated in the publication in 1880, of Muybridge's book, "The Human Figure in motion".

0.2.22. Futurism was the first of the modern groups to take movement as a central issue. Formed in Paris in 1909, it soon moved to Milan where the first world war saw its virtual demise. In an article in Le Figaro, by Marinetti, poet, dramatist, (eventual friend of Mussolini) and self appointed spokesman of the group, he announced,

"a new beauty (.....) a roaring motor car,
which runs like a machine-gun is more
beautiful than the winged victory of
Samothrace.' (29)

0.2.23. This was succeeded by a manifesto of Futurist painting in 1910. But the Technical Manifesto which appeared in the same year holds the key to the aesthetics of the movement. It reads:

'We proclaim that universal dynamism must
be rendered as dynamic sensation; that
movement, and light destroy the substance
of objects.' (30)

The manifesto on sculpture was written by the Sculptor Boccioni two years later in 1912.

0.2.24. It was probably the sculptor Medarro Rosso, with his studies of passengers features distorted by the continual jolting of fast moving trams, who led Boccioni, ⁽³¹⁾ and some of the painters to express movement in their work even before Marinetti had extolled its virtues. Other influences upon the group were the multiple exposures of cinematography and Cubism.

0.2.25. The combination of light and movement create their most dynamic sensation, as far as Futurist sculpture is concerned, in Boccioni's 'Bottle in Space' of 1912. In this sculpture, planes which are modelled to accentuate light on their broad surfaces and shade on their sides, imply an almost suicidal eccentric movement around an axis (the bottle) which appears on the point of disintegration. Dynamism is clearly the essential theme of this sculpture; the materiality of the bottle is quite definitely in the process of disintegration.

0.2.26. No matter how successful the bottle in space is as a piece of sculpture, it is clear that Boccioni had not grasped the implications of time. The Bottle in Space seeks to portray movement itself, and this was not a new phenomena in the visual arts. Before the twentieth century, artists interested in movement either showed movement arrested like a snapshot, (a series of snapshots in the case of the Bottle in Space) or alternatively they might imply it by composition and posture, as in Leonardo's Battle of Anghiari.

0.2.27. The first well recorded attempt at producing a Kinetic sculpture was made by the Sculptor Naum Gabo, in Moscow in 1920. ⁽²¹⁾ This sculpture, which Gabo has referred to as the 'technical, working Kinetic Model,' consists of a steel wire, vibrated by an electric motor. The purpose of the sculpture was to demonstrate to Gabo's students that perceived volume need not necessarily consist of mass. As a result the vibrations displayed by the wire were

considered in terms of an implied volume-defining system.

0.2.28. The making of this sculpture coincided with the publication by Gabo and his brother, Antoine Pevsner, of what they called the realistic Manifesto. ⁽³²⁾ In general, much of the thinking behind this manifesto owes its inspiration to the Russian movement known as Constructivism, and Constructivism in its turn owes a certain amount to Futurism. This is not surprising; the Realistic Manifesto was written after Gabo and Pevsner had studied in detail the manifestoes of the Futurists.

0.2.29. In common with the flood of manifestoes which appeared during the period 1920-1930, the Realist Manifesto attempts to denigrate other art movements of the time. For instance, it argues against the Futurists and Cubists,

"Ask any futurist how he imagines speed, and on the scene will appear a whole arsenal of raging automobiles, rumbling stations, tangled wire, the clang, bang, noise and ring of the whirling streets (.....) this is not at all required for speed and its rhythms. Look at a ray of sun - the quietest of the silent strengths - it runs three hundred thousand kilometers in a second. Our starry sky - does anyone hear it?"

But despite the argumentative tone of the first sentence, the second sentence has what Gabo calls 'The poetry of scientific motion', which influenced the Hungarian Moholy Nagy, and later the American Alexander Calder.

0.2.30. The manifesto also couches many of its ideas in scientific pretence. This is unfortunate since in borrowing words from another discipline the real meaning can be obscured. From the point of view of the Modern Movement, it contains some valuable considerations on the characteristics of planar surfaces. In a sentence which must

also relate to Gabo's vibrating wire, the manifesto recognises time as a fundamental element in the visual arts of today,

"We affirm in these arts a new element, the kinetic rhythms as the basic forms of our perception of real time."

0.2.31. From 1920 kinetic sculpture was becoming accepted as a viable area for artistic activity. Up until 1930 many painters and sculptors attempted the construction of kinetic sculptures, reliefs and even paintings. The majority were soon deterred by technical difficulties. Gabo summarised the dilemma as follows:

"Theoretically there is nothing to prevent the use of the time element, that is to say real motions, in painting or sculpture. For painting the film technique offers ample opportunity for this whenever a work of art wishes to express this kind of emotion. In sculpture there is no such opportunity and the problem is more difficult. Mechanics has not yet reached that stage of absolute perfection where it can produce mere motion in a sculptural work without killing, through the mechanical parts, the pure sculptural content; because the motion is of importance and not the mechanism which produces it. Thus the solution of this problem becomes a task for future generations." (21)

0.2.32. Like Gabo, Marcel Duchamp courted the possibilities of kinetic sculpture, but only for a short time. Duchamp collected together a series of what he called 'ready-mades'. One of the most celebrated of these, consists of the front fork and wheel of a bicycle, fixed to the seat of a stool. He also went on to produce a scheme, apparently for a kinetic sculpture, entitled 'The Bride

Stripped bare by her Batchelors'. This work is of an allegorical nature.

0.2.33. Generally, Duchamp's kinetic work is difficult to evaluate since it involves an assortment of obscure metaphysical and aesthetic implications. If Duchamp's kinetic work can be considered successful then it must be due to the fact that these metaphysical and aesthetic implications run far deeper than the actual kinetic movement. Duchamp, I am sure, would have agreed with this since in 1960 he was to describe mechanics as being unartistic.⁽³³⁾

0.2.34. Moholy Nagy, a Hungarian, began teaching at the Bauhaus in 1923. Soon after commencing this appointment he started constructing, through the use of modern industrial techniques, a series of kinetic constructions which he called 'Space Modulators'. In these he worked with movement in relation to light, which included the varying spectral intensities of visible light. It was his intention to project moving beams of light, often coloured, from these modulators into the sky. In so doing he hoped to produce spectacles as dramatic as a rainbow. In 1930 Moholy produced a programmed light robot, which was used as the hero of a film called 'Black, White and Grey'.⁽³⁴⁾

0.2.35. Comparison of Gabo's vibrating wire with Moholy Nagy's space modulators brings to the fore a dichotomy which existed as strongly then as it does now in kinetic art. This is concerned with two sorts of motion.

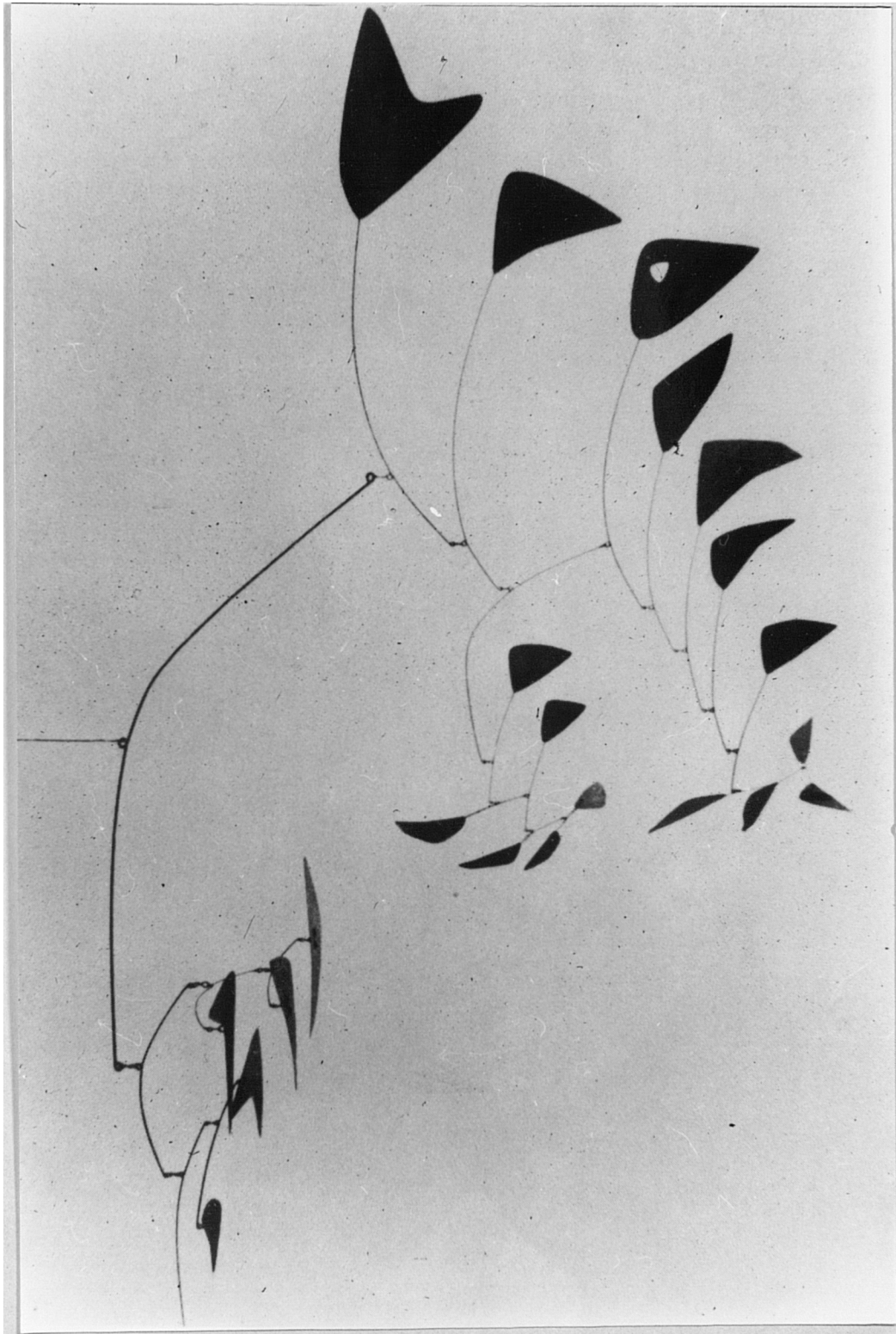
1. Motion in a sculptural work where one looks at the sculpture. Gabo's vibrating wire for instance.
2. Motion producing mechanism, such as the space modulator; where one looks away from the modulator in the direction of the imagery which its mechanism is producing.

0.2.36. It was the American sculptor Alexander Calder, who, more than anyone else, secured a position for kinetic sculpture. Calder commenced the construction of mobiles twelve years after Gabo's manifesto. These were first exhibited at the Gallery, Maeght in Paris, in 1932. The mobiles, which are usually suspended from the ceiling or a stand, consist of patterns of balance points and counterbalanced elements that are moved almost imperceptibly by apparently random currents of air, (See photograph, page 19) The resulting patterns of kinetic movement (the effect) owe their existence to particular hidden patterns, (the cause). What the spectator sees in these mobiles is a chain of cause and effect.

0.2.37. Calder's work automatically gives rise to another area of kinetic sculpture. Prior to Calder, the few examples of kinetic sculpture which existed were driven directly by some mechanical means, usually an electric motor. This power source usually led to a set of predetermined movements. What Calder has done, is to introduce to kinetic sculpture the possibilities which environmental stimuli offer in causing kinetic movement of a very different (not preprogrammed) kind. The work in this thesis is a natural extension of the area which Calder pioneered. The remainder of this chapter will be mainly concerned with this area.

0.2.38. After the second world war the possibilities of movement in art were taken up by younger men, many of whom worked in groups. These groups included, the "Groupe de Recherche d'Art Visuel" (GRAV) in Paris, in Italy the "New Tendency Artists", in Germany the "Zero Group", in Holland the N.U.L. group and in Spain, "Equipo 57." Meanwhile in South America, largely through contact with Max Bill, kinetic art took on a large following. In Britain and America there were no such polarisations.

0.2.39. A member of the GRAV group, the Argentinian Julio Le Park, worked mostly on metal reliefs. These reliefs explore such properties of light as shadow, highlight and reflection; many are operated by air currents in the same way as Calder's mobiles. At approximately



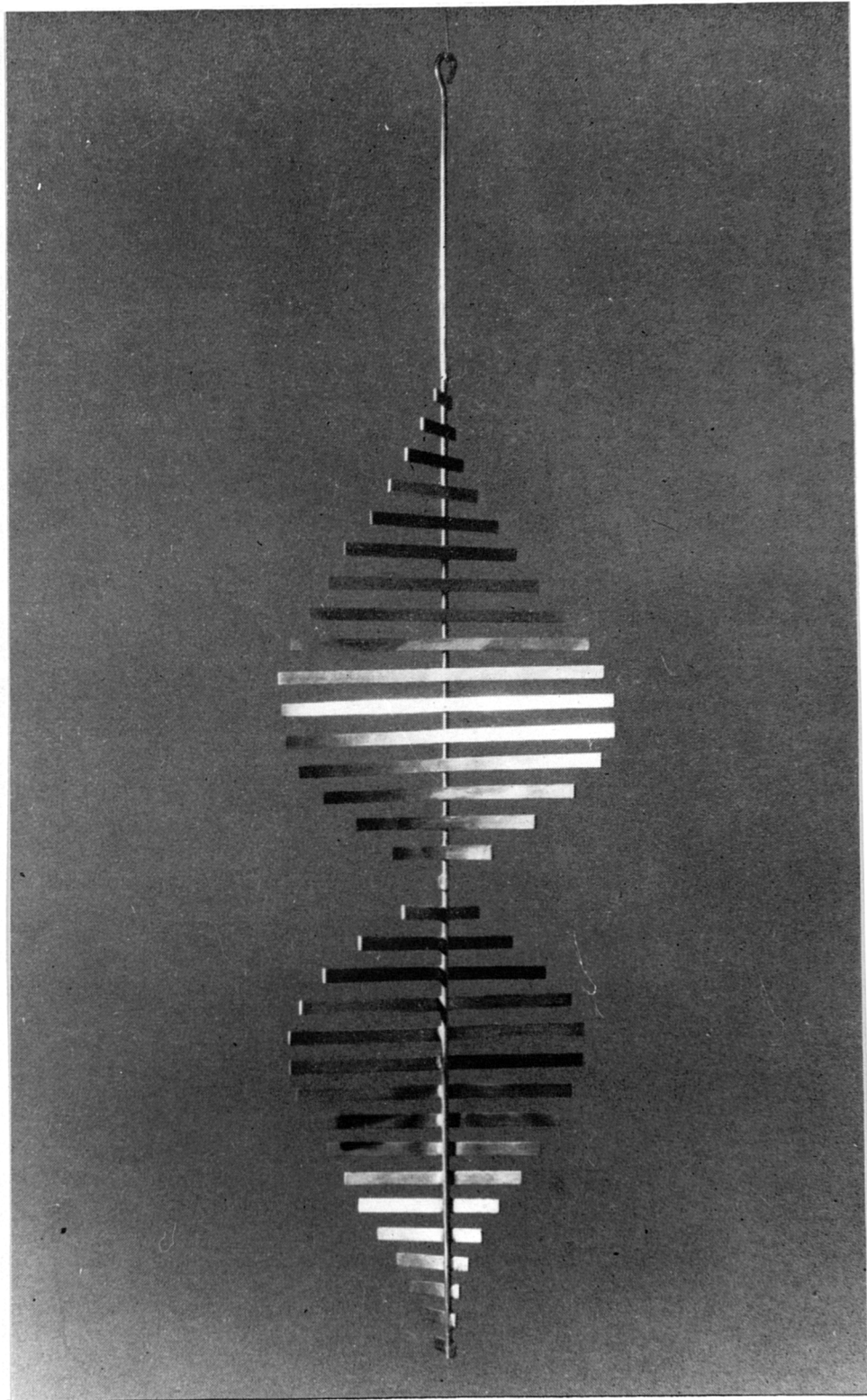
AN ALEXANDER CALDER MOBILE.

the same time, the Zero Group in Germany became increasingly concerned with the use of environmental phenomena such as temperature and air currents. This led to Hans Haake's 'Large Blue Sail' and his 'Weather Cube'.

0.2.40. In England the work of Kenneth and Mary Martin made use of the ever changing quality of natural light. Kenneth Martin went on to develop, among other things, his theme of rotation and reflection. In a series of suspended spirals (some are motorised) Martin uses natural air currents to gently, almost imperceptibly, rotate the work. This leaves the spectator to view a whole series of continually changing spatial and tonal relationships. One of these spirals is shown in the photograph on page 21.

0.2.41. In America, the kinetic sculptor George Rickey is the obvious successor to Calder. Rickey, as well as Calder, is particularly successful at developing forms and patterns of movement that are quite definitely related to air currents. But Rickey's vocabulary is far more adventurous than Calder's. In common with Calder, Rickey makes use of the possibilities of balance and counterbalance to which he often adds a strong feeling of instability. In Rickey's '8 Lines Horizontal', stainless steel blades rise and fall slowly, or rapidly when the wind is strong, and continually break and reform a plane. More recent work continues to examine the theme of balance and counterbalance.

0.2.42. The work of both Rickey and Calder also demonstrates one of the two distinct types of movement. This is movement by easily recognisable changes in position. It can be slow, almost imperceptible, rather like that shown by the hands of a clock. Alternatively there is the movement which occurs at speeds above the visual threshold, leading us to perceive only the results of the movement. One such example is Gabo's vibrating wire which has already been discussed. (See paragraphs 0.2.27-28) An example from every day life is the action of a variable egg beater, where the kinetic form of the beaters changes relative to the speed at which



A KENNETH MARTIN MOBILE.

they are driven.

0.2.43. In 1967 a group was formed in America called E.A.T., Experiments in Art and Technology. Its intention was to act as a matching agency between artists (often so-called kinetic artists) with specific projects and engineers competent to solve these problems. Despite the apparent technical expertise invested in this movement it has not yet produced any really profound flowering of a marriage between Art and Technology.

0.2.44. In Europe, the work of Nicholas Schöffer demonstrates the possibilities of a marriage between art and technology. Schöffer's work stems directly from the early work of Gabo and the space modulators on which Maholy Nagy worked during the inter-war years. Schöffer has made extensive explorations into movement, and what he calls dynamism. This has involved considerable experiment with the programming of his kinetic sculpture, which are usually driven by electric motors.

0.2.45. Schöffer's 'Spatic Dynamic, Cybernetic Tower', ⁽³⁵⁾ at Leige is possibly his most outstanding example of a sculpture where the moving parts are subject to the influence of external events. This tower, which is fifty-two metres high consists of thirty-seven elements, each turning on their axes at different speeds. Sixty-four sheets and blades of polished aluminium reflect rays of light over the city and into the sky. This tower, which is regulated by a computer and is sensitive to temperature and humidity, also produces noises based on street sounds and bird songs.

0.2.46. Schöffers's tower raises problems central to kinetic art which interacts in some way with the environment. It has already been stated (see paragraphs no. 0.2.36-38, 0.2.40-44) that in the kinetic work of Calder, Rickey and Kenneth Martin, it is obvious, through their choice of imagery, that air or wind currents are the cause of movement. Concerning Schöffer's choice of imagery, whether auditory or visual, the connection between the imagery and the stimuli

which help produce the imagery is questionable. Are temperature and humidity changes imaged successfully? Since this thesis is concerned with solar energy (which obviously includes temperature effects) some of the work in the following chapters relates specifically to this problem.

Background to Project

0.3.1. Initially there was considerable discussion in deciding how a project of this nature might start. It was eventually decided to survey as wide a range as possible of mechanisms and devices which respond to solar light and heat. From this survey a pattern of selection began to emerge concerning the applicability of certain solar responsive mechanisms suitable for this project. For instance, many areas (photobiology for instance) are still very much in their infancy, and it became apparent that work in these areas would involve a disproportionate amount of highly specialised, and sometimes dangerous, scientific research before they could become of use to this project.

0.3.2. As a result of this initial survey, it soon became obvious that, despite these limitations, the scope of this project was extensive and more than adequate for the time available. It was possible to make a deliberate selection of a series of devices and mechanisms for further investigation. These devices fit into the following areas,

1. Chemical
2. Photoelectrical
3. Mechanical

0.3.3. The majority of hardware for the experiments, the maquettes, and the full-size sculptures, were constructed in the Sculpture Department. Experiments were carried out in appropriate departments of the Polytechnic; Chemical in the School of Chemistry; Photoelectrical in the School of Physics and Mechanical in the Department of Physical Chemistry. These experiments were conducted with continual reference to actual and recorded conditions for this degree of latitude. These conditions formed the climatic parameters used in determining the sculpture.

0.3.4. The three areas were first studied in isolation and are discussed in the first chapter under the headings 'Chemical', 'Photoelectrical' and 'Mechanical'. The second chapter which involved the integrated use of Chemical, Photoelectrical and Mechanical devices, is divided into four sections with the headings, 'Chemical/Photoelectrical', 'Mechanical/Chemical', 'Mechanical/Photoelectrical' and 'Additional Developments'. The third chapter discusses the 'Further Developments', which have arisen as a direct result of the preceeding work. The forth and final chapter discusses the conclusions drawn from the work as a whole.

0.3.5. Through the work in this project, I would hope to demonstrate that patterns of movement can be developed, which express the existence of states of wholeness between the sun and devices with different technological bases.

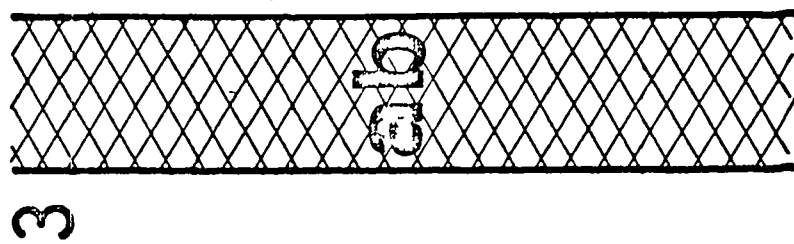
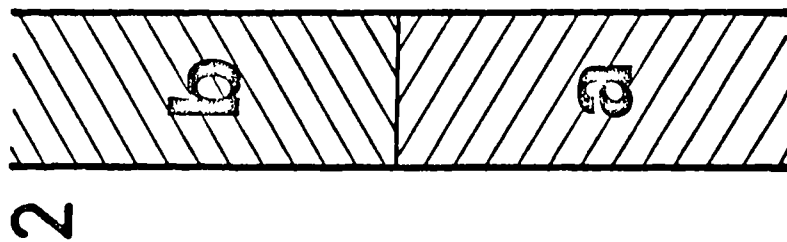
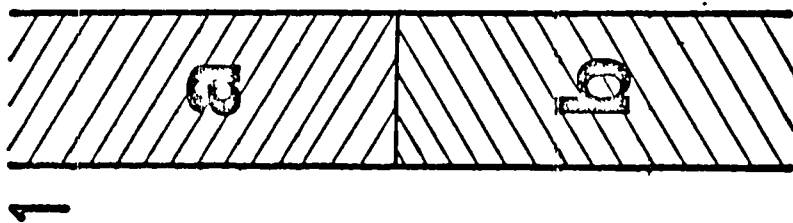
Chapter 1

The Chemical Area

1.1.1. It was decided to investigate the response to temperature of a particular case of liquid equilibrium in a three-component system. ⁽³⁶⁾ This system consists of two virtually immiscible liquids with very similar densities, and a third liquid with which they are both miscible. The third liquid changes its allegiance from one liquid to another according to temperature; this causes a change in the density of the two liquid phases. In a test tube the change in density can cause an inversion in the relative position of the two original liquid layers above a particular temperature. Eventually, at a high enough temperature, the two liquid phases become a single phase, (i.e. all the liquids become miscible) and the boundary between them disappears.

1.1.2. The behaviour of this three-phase system can be represented as follows;- (see diagram on page 27)

1. A test tube with liquid 'A' at the top and 'B' at the bottom, to which a dense liquid 'C', which is miscible in both 'A' and 'B' has been added.
2. A rise in temperature, causing liquid 'C' to transfer more of itself to liquid 'A'. The phase containing 'A' becomes the denser, and falls to the bottom. This is inversion.
3. A further rise in temperature causing liquids 'A', 'B' and 'C', all to become miscible. This is the single phase stage. As the temperature decreases the entire process is reversed.



THE THREE PHASES IN THE CHEMICAL SYSTEM.

1.1.3. A selection of liquids and their combinations were tested and phase diagrams were drawn up. These liquids included methanol (MeOH), cyclohexane ($\text{c-C}_6\text{H}_{12}$), n-octane ($\text{n-C}_8\text{H}_{18}$), carbon tetrachloride (CCl_4), petroleum ether, two star petrol, turpentine substitute and paraffin. In each test, one of the liquids was coloured to assist observation. Of the liquids mentioned, the combination of methanol and octane, to which carbon-tetrachloride was added, showed the most promise. (A more detailed account of these tests and of the three-phase system is given in section No. 1 of the appendix).

1.1.4. Further tests followed which determined the proportions of the liquids at a range of inversion temperatures from freezing to 20°C . Methanol and octane were kept at a constant 3.85 cm^3 and 4.50 cm^3 respectively. Carbon tetrachloride was added in quantities from 1.79 cm^3 - 2.40 cm^3 . At slightly above freezing, but less than 1°C , inversion occurred with 2.40 cm^3 carbon tetrachloride. Alternatively at 20°C (the temperature on a warm summer's day) inversion occurred with 1.79 cm^3 of carbon tetrachloride. Subsequent developments consisted of tuning a regular scale of inversion phases between the two temperatures by varying the amounts of carbon tetrachloride added to the methanol-octane mixture.

1.1.5. With a constant 3.85 cm^3 of methanol and a constant 4.50 cm^3 of octane, inversion occurred between 0°C and 20°C with the following amounts of carbon tetrachloride.

0°C	=	2.40 CCl_4
1°C	=	2.26 CCl_4
2°C	=	2.19 CCl_4
3°C	=	2.13 CCl_4
4°C	=	2.08 CCl_4
5°C	=	2.05 CCl_4
6°C	=	2.02 CCl_4
7°C	=	1.99 CCl_4
8°C	=	1.96 CCl_4

9°C	=	1.94 CCL ₄
10°C	=	1.92 CCL ₄
11°C	=	1.90 CCL ₄
12°C	=	1.88 CCL ₄
13°C	=	1.86 CCL ₄
14°C	=	1.85 CCL ₄
15°C	=	1.84 CCL ₄
16°C	=	1.83 CCL ₄
17°C	=	1.82 CCL ₄
18°C	=	1.81 CCL ₄
19°C	=	1.80 CCL ₄
20°C	=	1.79 CCL ₄

1.1.6. It was realised that if this system were to be used on a large scale it would involve considerable quantities of these liquids. This would be expensive, owing to the current cost of octane. As a result a further series of tests were carried out to try and find an alternative system.

1.1.7. In these tests, to reduce expense, 60-80 petroleum ether replaced octane. With the combination of petroleum ether, methanol and carbon tetrachloride a set of inversion sequences was arranged on a regular scale from 1°C - 30°C.

1.1.8. During the first two days of tests this sequence functioned predictably. After having been left at room temperature for two days the tests were repeated. These showed inconsistency in the temperatures at which many of the phase inversions were expected to take place. In one instance an inversion which was expected to take place at 5°C (proportions were 8.0cm³ 60-80 petroleum ether, 5.0cm³ MeOH and 2.70cm³ CCL₄) failed to invert when the temperature was taken up to 38°C. Even at this temperature none of the sequences became single-phase. Obviously this particular three-component system was subject to loss of equilibrium.

1.1.9. In the tests on the methanol, octane and carbon tetrachloride system, the methanol was coloured with either methyl violet or methyl orange, the octane having rejected both. Since a much wider range of colours was required, tests were carried out on various pigments and dyes.

1.1.10. The first tests were concerned with Reeves Artist Pigments. In each test the octane failed to accommodate the suspension of a pigment. In the methanol, suspension at first appeared successful, but over a period of five consecutive days precipitation occurred. Consequently alternatives were sought.

1.1.11. Tests again took place over a three week period, using Rotor Green and seven I.C.I., Waxoline dyes; the latter were, Green P.C., Yellow E., Orange E.P., Violet R., Blue A., Red O., and Sandoz Nitro Fast Green G.S.B. As in previous tests precipitation was immediate in the octane, but no precipitation occurred in the methanol. From the point of view of a successful range of primary colours the Waxoline dyes were the more satisfactory.

1.1.12. Conclusions pointed towards the use of the combination, methanol, octane and carbon tetrachloride as the most reliable; since in the tests

(a) The methanol showed no signs of colour precipitation.

(b) There was good separation from the octane during the phase inversion, and after a single-phase to two-phase transformation.

1.1.13. Initially a row of eighteen test tubes was assembled. The proportions of methanol, octane and carbon tetrachloride were tuned so that an inversion took place at every degree centigrade between 2°C - 20°C. (These proportions were identical to those listed in paragraph no. 1.1.5.) Use of the single-phase region was not considered, since it did not occur until 36°C, a temperature

only reached on a very hot summer's day. The methanol in each sequence was given a primary colour from the Waxoline range of dyes; consequently every phase inversion was accompanied by a change in the position of a primary colour.

1.1.14. By the use of a thermostatically controlled bath, and by reference to Meteorological Office information, ⁽³⁷⁾ (relating to temperature ranges on a selection of days) a variety of actual daily temperature cycles was simulated. The result was a series of inversion sequences which moved predictably up and down the eighteen points of the scale. These tests were again repeated with the addition of two further inversion sequences 0°C and 1°C.

1.1.15. The predictability of the system of inversion sequences discussed in the previous paragraph was technically desirable, since it enabled the quantitative development of a series of responses. However, the movement of sequences to and fro from a high to low temperature constituted only one movement which required extension if it was to become visually significant. This led to further tests with a row of test tubes, in which a main movement running from 1°C - 20°C, was contrasted with a random counter movement. Tests, (relating to temperature ranges on a variety of days ⁽³⁷⁾) showed that this idea of a main movement, within which ran a counter movement, had extremely rich possibilities.

1.1.16. In previous tests, colour changes had taken place in a predictable manner, with No.1. leading to No.2. and No.2. leading to No.3. etc. Now, No.1. would change, followed by No.2. and then No.3., (this was enough to set the main theme) then, for instance, No.4. would not change, but instead No.10 would change. A further rise in temperature would set the main theme again by Nos 5 and 6 changing, and so this theme continued as the temperature rose.

1.1.17. It was decided, as a result of the previous tests, to look for time patterns inherent in daily and monthly temperatures. According to Meteorological Office information, relating to average

maximum and minimum daily temperature, the average daily temperature for July and August is 20°C . ⁽³⁷⁾ (20°C is the highest average temperature in the year). This was the reason for not tuning the scale of inversion sequences above 20°C . On the other extreme the lowest average minimum temperature is 1.5°C . I preferred to commence tuning the scale of inversion sequences at just above freezing, (in between $0^{\circ}\text{C} - 1^{\circ}\text{C}$). This would enable the system to celebrate, in common with nature, any rise in temperature above freezing.

1.1.18. The months of the year with the lowest temperatures are January, February, March and October, November, December. The months with the higher temperatures are, of course, April, May, June and July, August, September. I decided to attempt a series of contrasts by grouping a set of low with a set of high temperatures. As a result the months January, February, March were paired with July, August, September. Alternatively, April, May, June, were paired with October, November, December. The pairing was emphasised by colour as follows:

January, February, March	- Yellow	}	Warm Colour
July, August, September	- Red		
April, May, June	- Green	}	Cold Colour
October, November, December	- Blue		

The actual temperature bands occupied by these groupings are:

→ $1^{\circ}\text{C} - 8^{\circ}\text{C}$	January, February, March	= 8 changes	
→ $6^{\circ}\text{C} - 13^{\circ}\text{C}$	April, May, June	= 13	"
→ $11^{\circ}\text{C} - 20^{\circ}\text{C}$	July, August, September	= 10	"
→ $4^{\circ}\text{C} - 14^{\circ}\text{C}$	October, November, December	= <u>11</u>	"
		42	"
		<hr/>	

1.1.19. From 1 - 42 (the total number of changes) there are 13 prime integers. The prime integers were inverted so that the highest prime became the lowest. This is shown in detail on page no 34. In this way the non-prime integers represent the natural (main) theme of movement, whilst the prime integers represent a synthetic (counter) movement. The inversion sequence commences at the smallest non-prime integer position, and moves up the scale of non-primes as the temperature rises. With the prime integer positions the movement is reversed, commencing at the highest integer in the sequence and continuing down to the lowest.

1.1.20. A maquette making use of this sequence was developed. In this maquette colour gradually disappears as the temperature increases, and reappears as the temperature decreases. This sequence is shown in the photograph on page 35, which shows the behaviour of the maquette over a range of temperatures. The sequence is achieved by colour being visible before, but hidden after, inversion. Consequently a hot summer's day would be represented by an absence of colour, whilst a cold winter's day would be accompanied by colour. At dawn and dusk the rate of change would be the greatest.

1.1.21. This maquette consists of eight poles arranged as in the perspective drawing on page no. 36. In this arrangement the eight poles imply (among other things) two planes, one of which is interspersed with blue and green, the other with red and yellow. These run diagonally across the four poles, the number of diagonals depending on the temperature range. Red and yellow start their temperature rise from the top left and right hand side respectively. Blue and green commence their temperature rise from the bottom left and right hand side respectively. The side at which the colours commence their temperature rise determines an order of priority. For instance, green commences its temperature rise at the bottom right-hand side and is assigned priority over blue on this side. Therefore if blue comes within a chosen distance (5mm) to green, then green cancels blue.

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 TEMPERATURE RANGE

1 ② ③ ④ ⑤ ⑥ ⑦ ⑧ = JANUARY FEBRUARY MARCH.

1 2 3 4 5 6 7 8
M L K J I

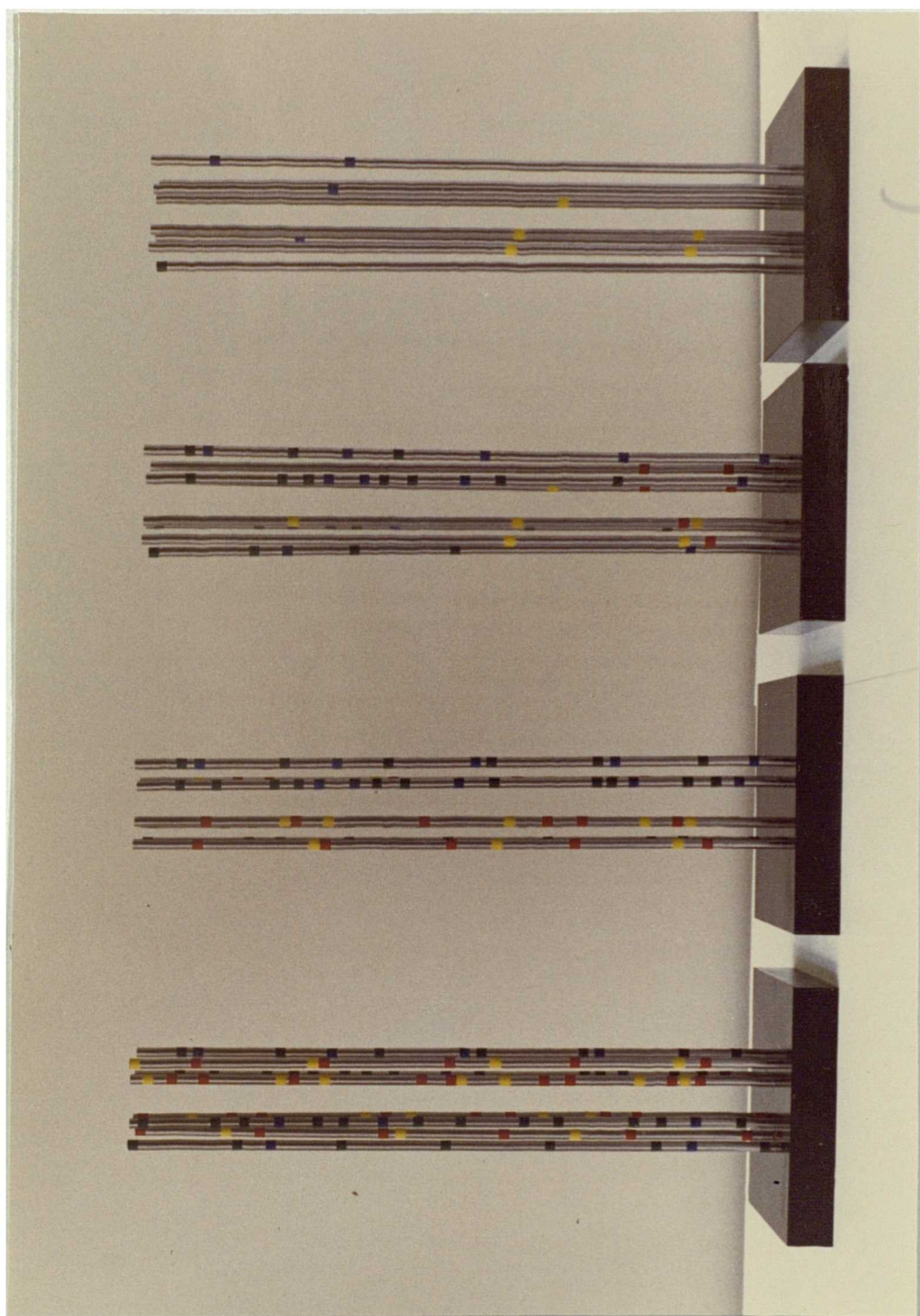
1 2 3 4 5 6 7 8 9 10 11 12 13 = APRIL MAY JUNE.
9 10 11 12 13 14 15 16 17 18 19 20 21
I H F

1 ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨ ⑩ = JULY AUGUST SEPTEMBER.
22 23 24 25 26 27 28 29 30 31
E D C

1 2 3 4 5 6 7 8 9 ⑩ 11 = OCTOBER NOVEMBER DECEMBER.
32 33 34 35 36 37 38 39 40 41 42
B A

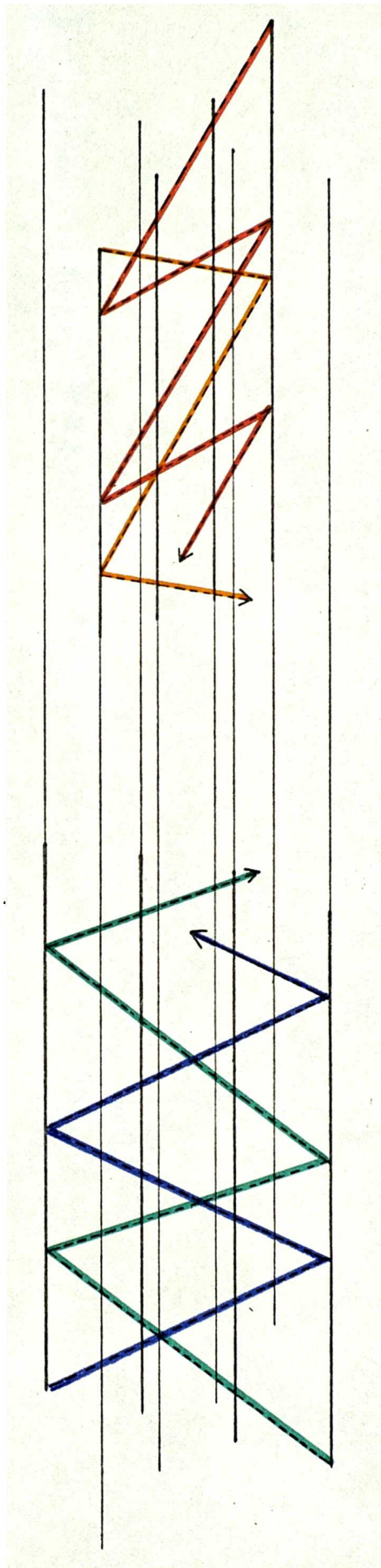
Figures in large print represent number of changes available in each of four sets and take the form of a natural time sequence governed by climatic change. Circled figures in large print are primes and represent a synthetic time sequence (see below). Each of the four sets is allocated a colour. Maximum interaction occurs between 6°-8°C and 11-13°C.

M L K J I H G F D C B A
1 ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨ ⑩ 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42
13°C 9°C 20°C 18°C 12°C 16°C 14°C 10°C 14°C 10°C 8°C 7°C 5°C 3°C 2°C

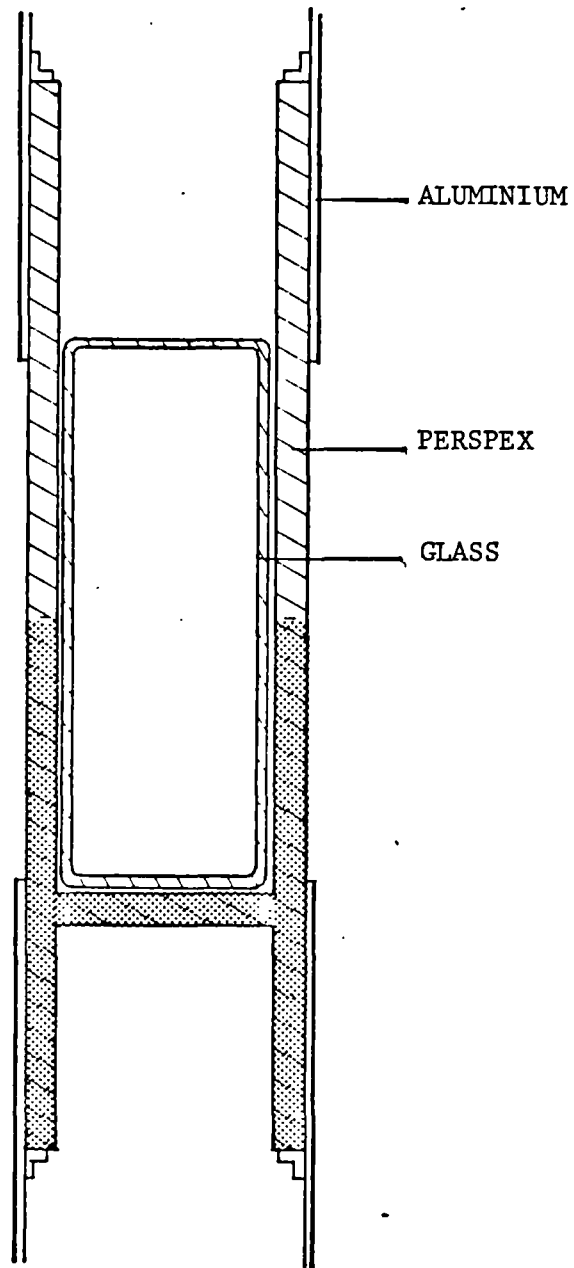


1°C 8°C 14°C 18°C

MAQUETTES SHOWING SEQUENCE OF COLOUR CHANGES BETWEEN 1°C - 18°C. HEIGHT 18".



DRAWING SHOWING MOVEMENT
OF COLOURS.



SECTION DRAWING OF HOUSING FOR THE THREE-COMPONENT
CHEMICAL SYSTEM.

1.1.22. Each of the three-component chemical systems is contained in a glass cylinder. This glass cylinder is fitted into a Perspex sleeve, the latter having a transparent top and an opaque bottom half. Finally, the Perspex sleeve, (containing the glass cylinder) is slid into aluminium poles as in the drawing on page 37.

Initial Conclusions to the Chemical Area

1.1.23. Over two years has elapsed since the row of test tubes containing the three component system was assembled. (see paragraph no. 1.1.16) From October 1975 - April 1976 the test tubes remained outside and were observed at regular intervals. After a period of three months it was noticed that; -

- (a) Part of the sequence suffered a loss of equilibrium; (equilibrium was restored by agitating the liquids).
- (b) The dyes had begun to fade, many were no longer visible. As a result, changes in the system were no longer readily identifiable.

1.1.24. Despite the problem of loss of equilibrium, this area was very instructive since it introduced me to meteorological patterns in the form of temperature bands and cycles. From this information patterns of temperature change were selected, (the groupings of months and the temperature range from 0 - 20°C). This led to the theme of natural (main) and synthetic (counter) movements described in paragraph no. 1.1.16.

1.1.25. As a result of this chemical area, the study of meteorological information became an essential precondition to the development of kinetic sculpture which uses the light and heat from the sun.

Photoelectrical Area

1.2.1. In this area a variety of photoelectrical devices have been investigated. These have been used as control mechanisms which, whilst responding to sunlight, require the additional input of an external and independent power supply. This additional input makes the area essentially different from either the Chemical or Mechanical areas, since each of the latter rely directly on the sun, and require no additional power supply.

1.2.2. Work in this area has dealt with:

- (1) The construction and use of a number of circuits which respond to a series of illumination thresholds in the visible spectrum.
- (2) A digital volt meter, used in conjunction with a sample and hold circuit.
- (3) A light level indicator.
- (4) A multivibrator.
- (5) A spectral intensity measuring device.
- (6) A frequency modulator circuit.

1.2.3. (i) Twelve identical circuits were constructed in which a voltage relay was energised by light falling on a light dependent resistor. ⁽⁴⁰⁾ These circuits were tuned to respond to a sequence of illumination levels by:

- (a) Adjusting the potentiometer to the required value.
- (b) Placing varying combinations of Kodak no. 96 neutral density filters over the sensitive face of an O.R.P. 12, light dependent resistor.

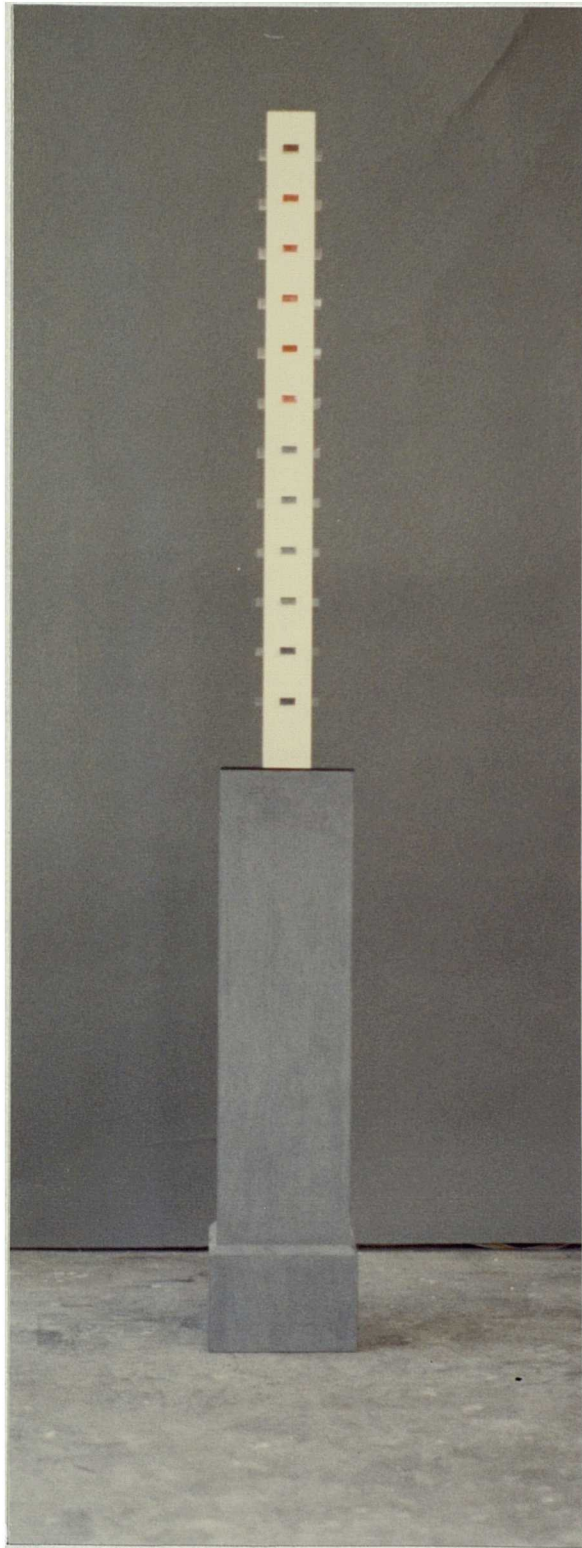
1.2.4. This section was assisted by the construction and subsequent use of a maquette, which consists of a 3' high, square section Perspex tower, (see photograph on page 41) in which twelve Perspex lenses were located at twelve equal and common intervals in each of the four faces of the maquette. The grooves, situated $\frac{1}{4}$ " away from the corners were cut to emphasise the edge and verticality of the maquette. This causes a visual balance between the projecting lenses, which implies twelve horizontal planes stacked vertically.

1.2.5. The top six and bottom six lenses on each face of the maquette were coloured red and green respectively. Twelve, twenty-four volt light bulbs were introduced inside the maquette, and each of these light bulbs corresponded with a horizontal set of four lenses. Each of these light bulbs could be switched on or off by the relay incorporated in each of the circuits.

1.2.6. Through the circuits, and with the use of a controlled light source and Lux meter, the maquette was tuned to respond to:

- (a) The Meteorological Office mean illumination level for any one month or period.
- (b) The Meteorological Office maximum and minimum illumination levels for any one month or period.
- (c) A selection of illumination levels between the Meteorological Office maximum and minimum for any one month or period. (These levels of illumination were based on the information supplied in section no. 2 of the appendix)

1.2.7. The mid point of the maquette, in between the green and red lenses, represented the statistical mean for the relevant month. The on/off settings to the light bulbs which are adjustable, were based on an equally spaced, or a logarithmic progression of illumination levels above and below the mean for that month. The



MAQUETTE. TOTAL HEIGHT 6' 6".

bottom green lense represented the minimum, whilst the top red lense represented the maximum illumination level.

1.2.8. The response of the maquette was as follows. As the actual illumination level rose above the mean the red lenses would light up, (a rise in illumination corresponding with the maximum setting for that month, causing all the red lenses to light up). The same response applied to illumination levels below, with the exception that the lenses were green.

1.2.9. (2) The construction and use of the digital volt meter and sample and hold circuits grew out of the need for a more automatic flexibility. This was not possible with the previous twelve light sensitive voltage relay circuits.

1.2.10. The sample and hold circuit is described diagrammatically on the following page, (the circuit diagram can be found in section 3 of the appendix). The circuit gives rise to a continuous process in which the illumination level is sampled for thirty seconds. The sampling is continually compared with the mean, which is logged in the hold circuit, the latter having been arrived at from the previous thirty seconds of illumination. The difference between the actual illumination level and that held by the memory is characterised by a proportionate rise or fall in voltage.

1.2.11. As with the previous twelve circuits (see paragraphs 1.2.7-8) the results were observed through the use of the Perspex maquette. This was employed in much the same way as before. For instance, an illumination level above the mean would light up a set of four lenses. The position of these four lenses relative to the midpoint of the maquette, depended on the proximity of actual conditions to those logged in the hold circuit. If for instance, conditions were almost identical, the green and red lenses situated immediately on either side of the mid point of the maquette, would light up. Alternatively, if actual illumination levels diverged widely from the previous thirty seconds of activity, then lenses further away from the mid point would be lit. In all there were six

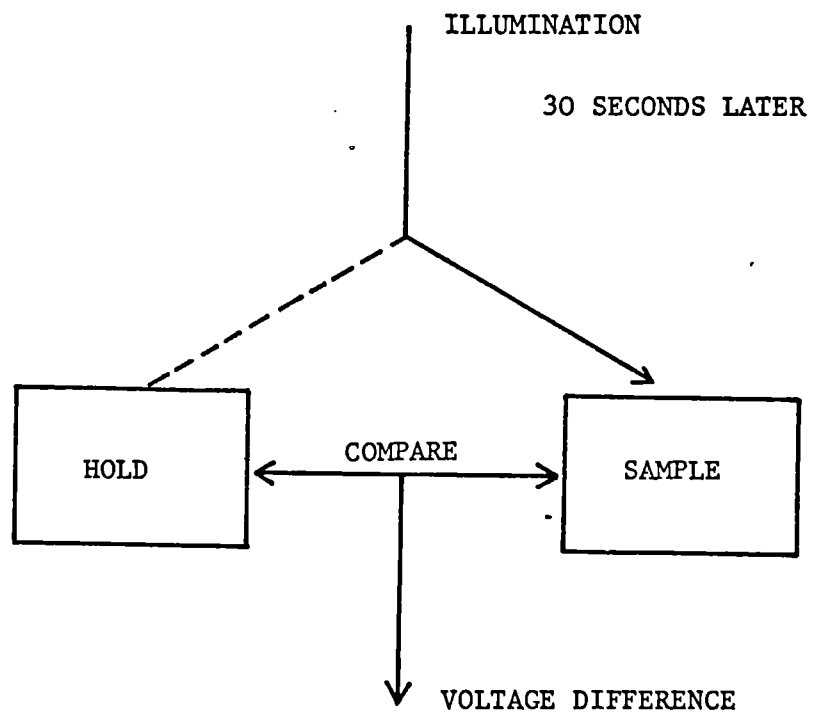
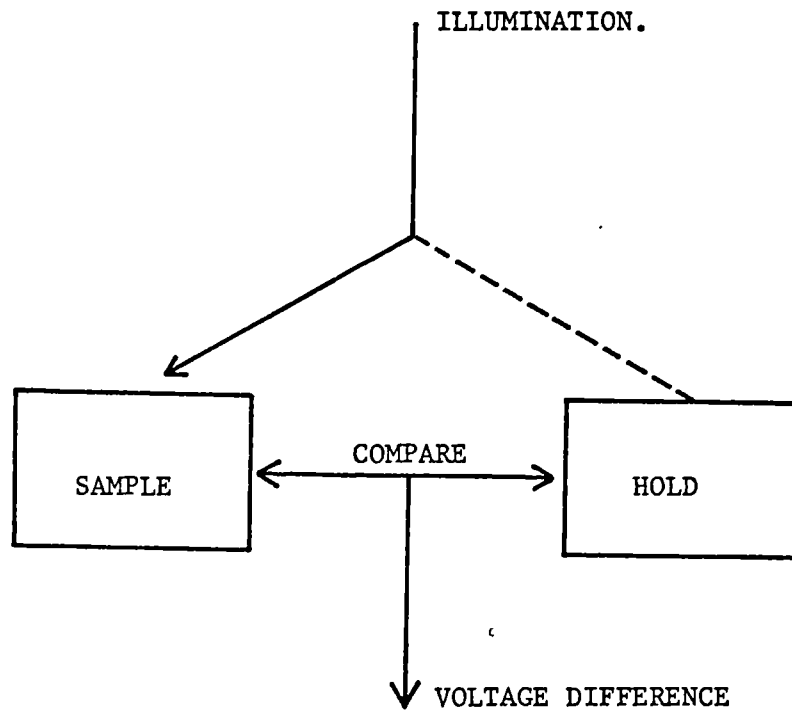


DIAGRAM SHOWING SAMPLE AND HOLD CIRCUIT SEQUENCE.

stages of divergence, divergence being the greatest when the lenses at the extreme top and bottom of the maquette lit up.

1.2.12. (3) The light level indicator, which consists of an array of sixty light-emitting diodes, ⁽³⁹⁾ gave rise to a wide range of responses to illumination levels. The response could be altered by either expanding or contracting the scale covered by the diodes. For instance, on a day when cloud cover was intermittent, and variations in light intensity were wide and frequent, the scale could be expanded to encompass this extensive range. On a day of constant cloud cover, this scale could be compressed to cover the narrow range of illumination levels.

1.2.13. However, it was realised that the frequent readjustment of the range of illumination levels would break the link between the kinetic activity of a sculpture and its response to natural phenomena. This would be caused through the intrusion of an operator, (the sculptor or observer for instance) and could have far reaching implications. Observations of this device have shown, that whilst this readjustment leads to almost continual kinetic activity, there is also the danger of the kinetic activity being similar, regardless of the time of year, and whether the day be sunny or cloudy.

1.2.14. (4) The multivibrator was built to control an artificial light source which could be incorporated in a kinetic sculpture. By observing a 12 volt electric light bulb which was built into an arm of the multivibrator, it was realised that -

- (a) The multivibrator would enable the illumination of a kinetic sculpture to become brighter as the natural illumination diminished, thus enabling a counter movement to be established.
- (b) The multivibrator would enable the illumination of a kinetic sculpture to rise or fall in proportion to the actual rise and fall in natural illumination.

1.2.15.(5) The spectral intensity measuring device consists of six identical circuits, ⁽⁴⁰⁾ each of which trigger the on/off settings of a 12 volt electric light bulb. Kodak Wratten filters, nos 70, 72B, 73, 74, 75 and 76 were arranged over the photodiodes, thus dividing the visible spectrum into six bands, each approximately 50 nm. wide. ⁽⁴¹⁾ The colours of the spectrum represented by these six bands are violet, blue, green, yellow, orange and red.

1.2.16. The device was tested and it was observed, through the response of the electric light bulbs, that the blue end of the spectrum predominated for the majority of the day, in spite of compensatory adjustments to the potentiometers. This was counteracted by the addition of Kodak neutral density filters, which enabled a series of responses over the whole of the spectrum to be obtained.

1.2.17.(6) The frequency modulator circuit was developed in response to observations concerning sudden changes in light intensity levels. Often, the period during which such changes occur is so minute, that the complexity of the change cannot be comprehended in real time. To examine the problem, the frequency modulator was connected to an audio tape recorder utilizing a phase-locked loop (see appendix section 4). This enabled sudden changes to be played back and comprehended through the expansion of their time duration. But in so doing, there appeared to be a danger of destroying the simultaneity of events between sun, sculpture and observer.

Initial Conclusions to the Photoelectrical Area

1.2.18. Investigation in this area soon became at least as concerned with the development of photoelectrical devices, as it did with sculptural form. This led to the construction of a range of technical devices, capable of responding in a variety of ways, and by a variety of methods, to sunlight.

1.2.19. Originally it was decided to develop a scheme around the circuit dealt with in section No. 1, and also make a spectral intensity measuring device as in section No. 5. In many ways sections No. 2, 3, 4 and 6 developed out of the limitations of these other two sections.

1.2.20. It was observed that during extremely minor fluctuations in sunlight, the reaction of the tower maquette, if controlled by the twelve circuits in section No. 1. was static. The circuits used in sections 2, 3, 4 and 6 were developed as a more sensitive response to very minor fluctuations in sunlight.

1.2.21. Soon after I commenced the technical work in this section I began the construction of the Perspex tower maquette, (see paragraphs 1.2.3-8). Initially, this was constructed in conjunction with the set of twelve circuits ⁽³⁸⁾ which were tuned to respond to a series of illumination thresholds. This maquette was merely used, not developed, for the digital volt meter and sample and hold circuits. In this latter instance, the maquette served to examine some of the aesthetic possibilities of a system which monitors the divergence between actual and predicted conditions.

The Mechanical Area

1.3.1. In this area it was decided to select a mechanical device which moved as a direct response to the sun. This resulted in an investigation into the use of heat sensitive pistons as power sources for kinetic sculpture. The pistons which were eventually selected, are used domestically as automatic greenhouse vent openers, and work by the expansion and contraction of wax which is constrained in the cylinder. One of these pistons is shown in the photograph on the following page.

1.3.2. The cheapest and most easily available piston, with the greatest displacement was (at this particular time) produced by Thermoforce Ltd. The design which was tested, has an external barrel length of 250 mms., and external diameter of 15 mms. and is filled with paraffin wax. The piston barrel was painted black, and mounted at the focal point of a 150 mms. wide parabolic reflector. The latter was rolled from a sheet of mirror finish stainless steel.

1.3.3. The performance of the piston was monitored over an eight week period by recording the resistance of a 100 mms. coiled heater element, at twenty minute intervals using a data logger. (see appendix nos 5-6) The element had one end fixed a few centimetres below the surface of a column of mercury, the other end being attached to the piston's push rod. The length of the exposed element consequently varied, and thus the wire served to measure the extension of the piston.

1.3.4. Movements of up to 2.5 mms. were recorded during settled periods of climatic activity whilst in unsettled periods (intermittent cloud cover for instance) movement was extensive. Tests also proved the piston capable of giving a maximum displacement of 65 mms. at 19°C to a load of up to 30 kgs. Only after this load was exceeded was there a significant loss in efficiency. It was also noted that the heavier the load, the more jerky was the piston's performance. It appeared there were a number of pronounced energy peaks, with a load exceeding 25 kgs. Consequently the piston required a critical amount of inertia to surmount these peaks. Given this the piston



A THERMOFORCE PISTON.

would jerk in its performance from peak to peak.

1.3.5. During these tests the piston was also observed to have a built-in time delay. A sudden change in temperature did not usually cause the piston to increase its displacement immediately. This was because displacement is conditioned by the time it takes the wax to change its volume relative to a change in temperature. Consequently it was not uncommon to observe a one minute delay.

1.3.6. Observations proved this piston to be a direct and sensitive method of achieving a response from the sun. It was next considered how the response of the piston could be amplified.

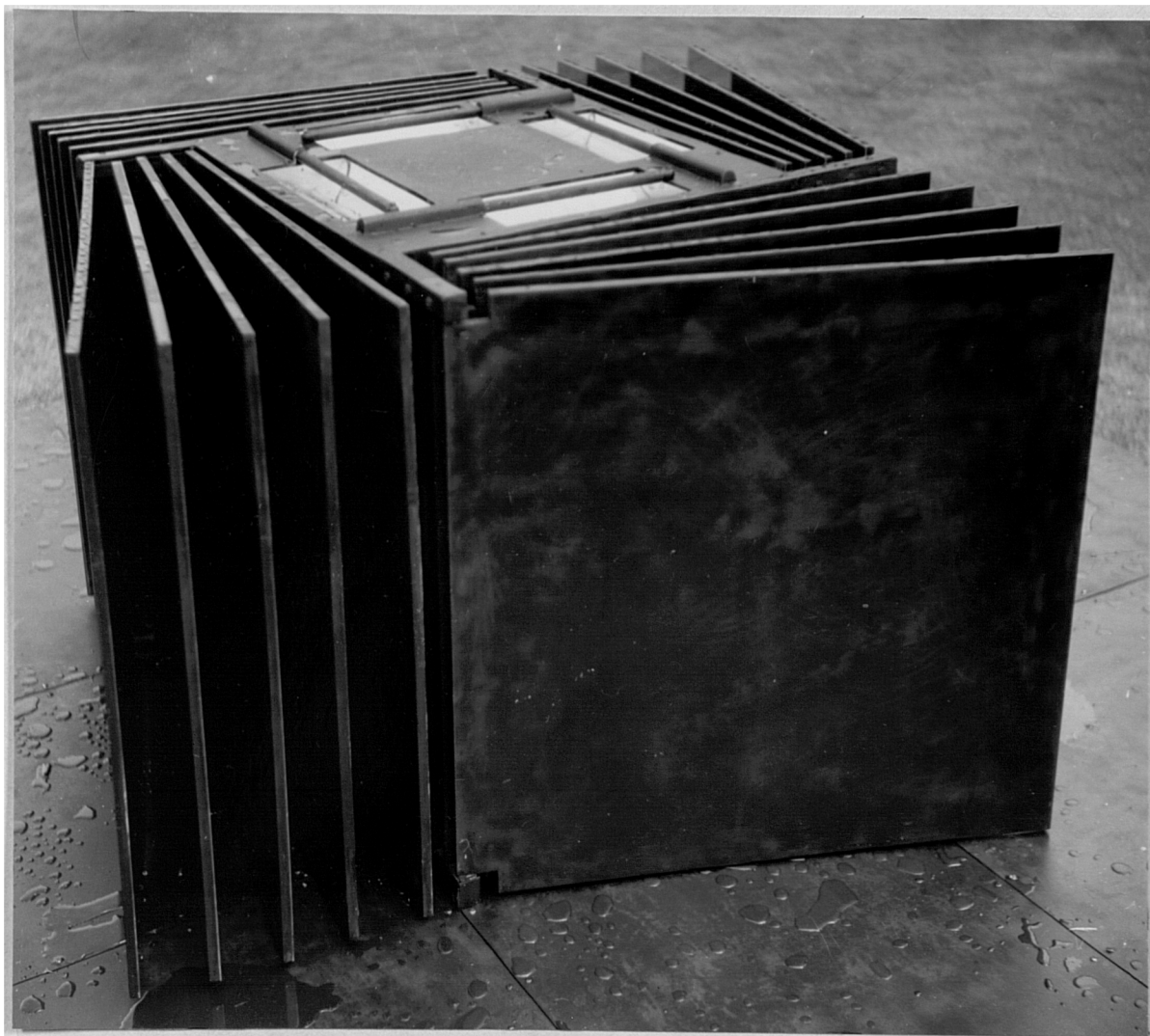
1.3.7. By conducting a series of experiments involving gears and simple lever actions, the maximum 65 mms. displacement of the piston was amplified to give a much greater range of movement. Even by constructing a gearbox from Meccano parts it was possible to convert this displacement into forty-five revolutions. However, at this scale, and with the natural limitations of Meccano gears, there was a very significant loss of torque.

1.3.8. A sculpture incorporating four of these pistons has been constructed (see photographs on pages 50-52). In this sculpture each of the pistons drives a rack which rotates a pinion, (see drawing on page 53). The pinion, (which is attached to a spindle) operates a drum, to which a cord is attached; this then opens and closes a simple lever action mechanism. The final result is the movement by each piston, of five reflective/non-reflective planes about a common spine.

1.3.9. This sculpture which is 2.5 m. square was constructed first by building a steel frame from 3/16" thick, 1" L section, mild steel. This was covered, by the use of self tapping screws, with 3/16" thick, slate grey glass reinforced polyester. For storage purposes this frame was designed to dismantle into three sections of equal length; the middle section taking the centre piece frame and the driving mechanism.

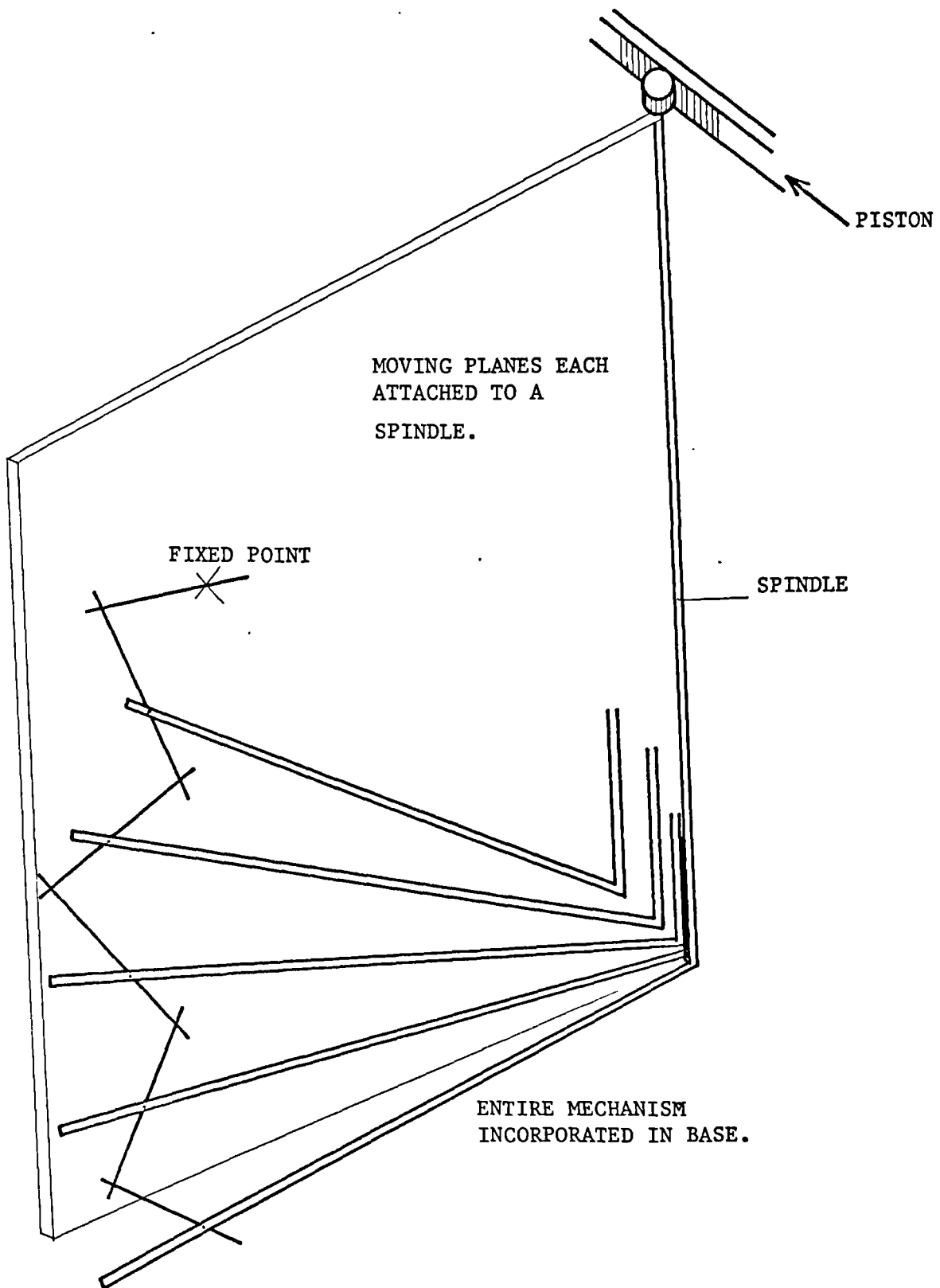


PISTON OPERATED SCULPTURE. BASE 2.5 x 2.5 M.



VIEW OF CENTRAL BOX, SHOWING POSITION OF PLANES, PISTONS, AND PARABOLIC REFLECTORS.





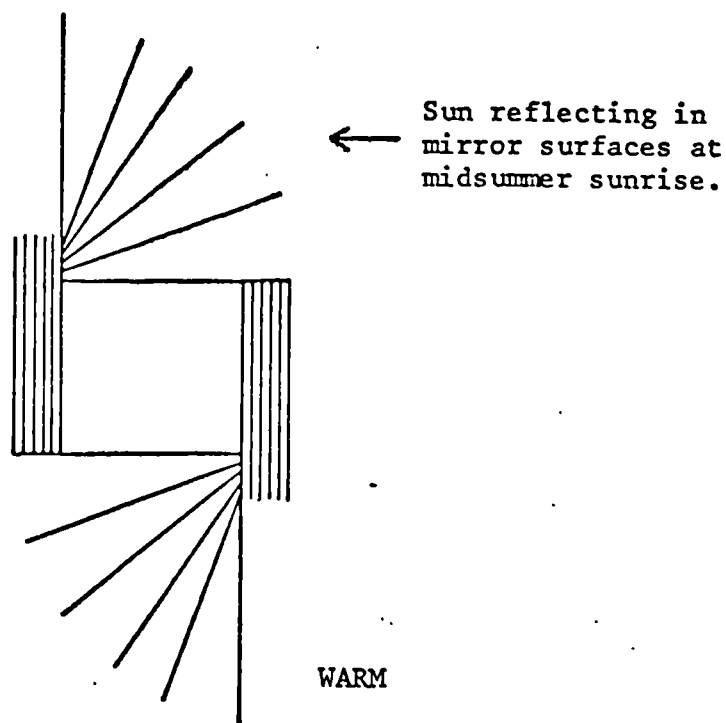
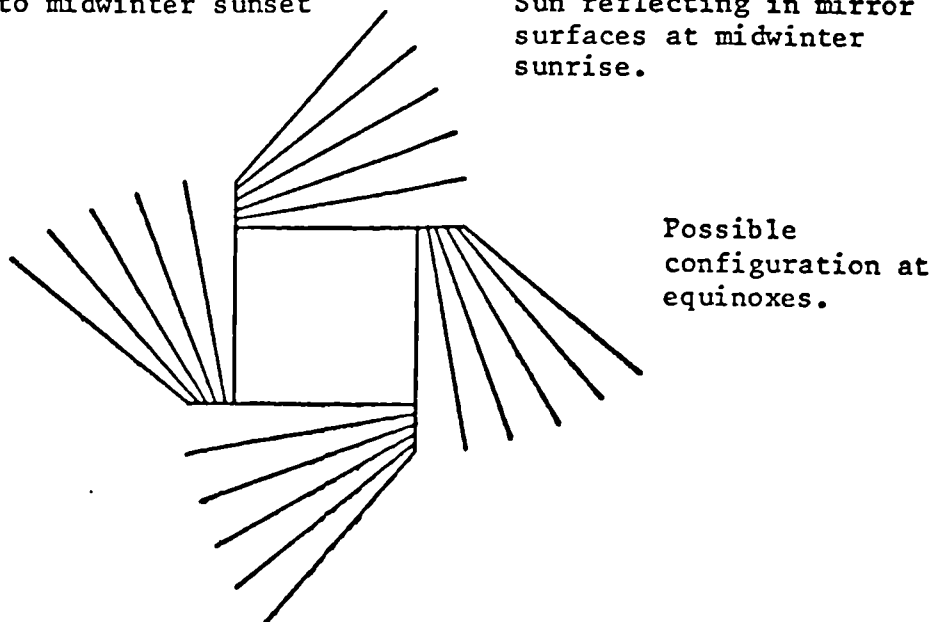
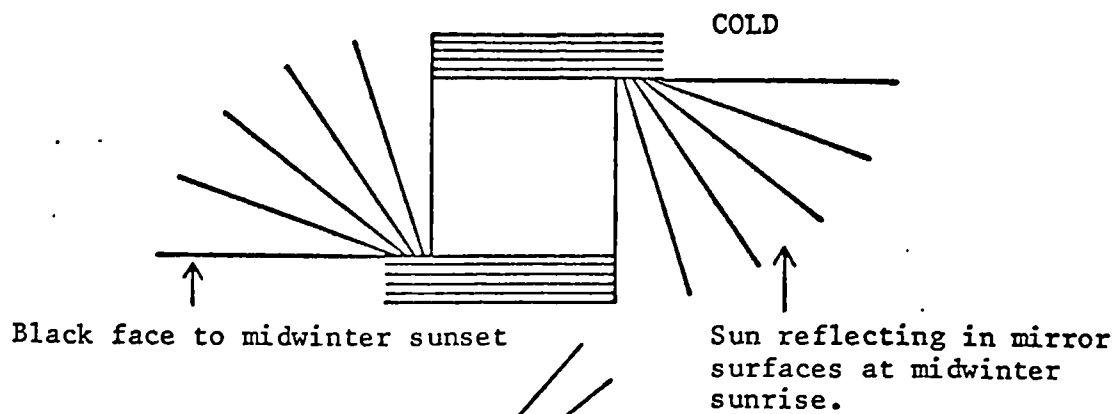
DRAWING OF MECHANISM WHICH OPERATES THE MOVING PLANES.

1.3.10. The slate grey in the sculpture was achieved through the presence of slate powder (60% slate powder, 40% polyester resin with black pigment) mixed into the top coat of the polyester resin. This top coat was later rubbed down with a medium grade soda block to dull the surface. This was followed by the application of oil, which was rubbed into the exterior surface of the polyester.

1.3.11. The insides of the twenty planes were covered with 20 gauge stainless steel sheets. These sheets have a mirror finish on the outside. On the inside they are matt, this enabled the matt side to be glued to the polyester with Bostik 20/24 epoxy glue.

1.3.12. The combination of slate and stainless steel was chosen because of the visual contrast of the two materials. Stainless steel could reflect and naturally absorb the environment as the planes opened, whilst the dull slate grey surface could expel the environment as the planes closed. It was also hoped that minor changes in temperature would be magnified, since even movements through only one or two degrees could cause substantial changes to the perceptual nature of the environment as reflected in the planes.

1.3.13. Initially, I wanted the sculpture to exhibit two basic states, one which would predominate around midwinter, and the other around midsummer. The first consideration involved the sculpture opening out all of its planes as the temperature increased towards the summer; then closing as the temperature decreased towards the winter. A series of tests were conducted to explore this possibility. From these I realised that, whatever the temperature change, the relationship of the spaces between the planes showed a sameness, there being no significant spatial contrasts. I then considered the alternative of the planes on two opposing sides of the sculpture opening as the temperature increased, and the planes on the other sides closing. The reverse would occur when the temperature decreased, (see diagram on page 55). This pattern of movement was finally adopted.



DIAGRAMS SHOWING SEASONAL RESPONSE OF PISTON
OPERATED SCULPTURE.

1.3.14. As shown in the diagram, the positioning of the sculpture in relation to the four points of the compass must be observed if the movement of the sculpture is to relate to the seasons. In midwinter, the sunrise is reflected in the stainless steel mirror surfaces on the east facing side of the sculpture. During summer, the planes on the north facing side of the sculpture reflect the sunrise.

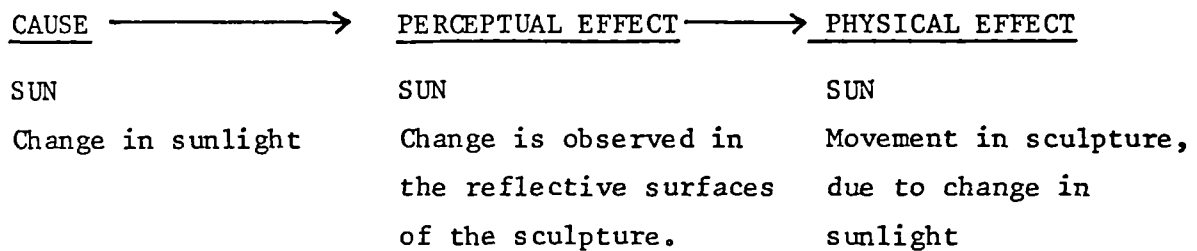
Initial Conclusions to the Mechanical Area

1.3.15. Observations of the sculpture constructed in this area, have shown that movement always occurs at speeds well within the perceptual threshold. This can be categorised as movement by change of position, as defined in paragraph 0.2.42. of the introduction. But this categorisation can be misleading, since within it the sculpture demonstrates the existence of movement on two very distinct levels. These are as follows, -

- (a) A group of sudden but slight changes in the temperature of the piston, (caused perhaps by thin clouds passing over the sun, or intermittent currents of cooler air circulating over the piston) usually resulting in a type of staccato movement in which the outside edges of the planes suddenly move a distance of no more than half an inch. Such movements are frequently magnified through the reflective surfaces of the stainless steel planes.
- (b) An extensive change in the temperature of the piston (such as when the sun becomes obscured by dense cloud) causing a less tentative and much greater degree of movement. In this case

there is a lack of staccato movement, the planes move gradually but positively.

1.3.16. Apart from the development of a link between the two basic configurations of the sculpture and the solstices (see diagram on page 55); there is also the vitally important link which the observer becomes aware of between the behaviour of the fibre glass and stainless steel sheets and the sun. In reflecting the environment the stainless steel sheets exhibit a series of facets of the surrounding landscape. Therefore, variations in the quality of sunlight on the landscape, are simultaneously reflected in the sculpture. These fluctuations are then followed by the movement of the planes. The observer therefore witnesses a sequence of visual cause and effect relationships which are as follows, -



General Conclusions to the Chemical, Photoelectrical
and Mechanical Areas

1.4.1. A number of inventions have been studied, and their ability to activate patterns of kinetic movement as a specific response to particular states of solar light and heat have been observed. This has taken into account,

1. Movement and counter movement, involving the use of a main movement, which was seen to respond to changes in solar temperature. This main movement was contrasted with a secondary movement, which made the main movement all the more significant, (Chemical, paragraphs 1.1.19.).
2. Similarity and contrast, e.g. similarity - sculpture displaying a warm colour on a warm day. Contrast - sculpture displaying a cool colour on a warm day. (Chemical, paragraphs 1.1.20.)
3. The development of configurations in the sculpture to signify specific sun/earth relationships, i.e. solstices (Mechanical, paragraphs 1.3.13-14).
4. The use of control mechanisms, which respond to sunlight, but require the additional input of an external and independent power supply. (Photoelectrical, paragraph 1.2.1.)
5. Illumination intensity rescaling, in which kinetic movement can become almost continual by either the sculptor or spectator and readjusting the response of the sculpture or maquette to varying ranges of illumination. (Photoelectrical, paragraphs 1.2.12-13)

6. Time rescaling, in which changes in illumination which are too complex to be comprehended by the spectator, are given an expanded time duration. (Photoelectrical, paragraph 1.2.17.)
7. Actual and predicted conditions, where kinetic movement is a response to the divergence between actual and predicted conditions. (Photoelectrical, paragraph 1.2.6.)
8. Time delay, caused by the effect of changes in temperature on wax filled pistons (Mechanical, paragraph 1.3.5.).
9. Staccato and legato movements, extensive changes in temperature causing legato movements, minor changes in temperature causing staccato movements. (Mechanical, paragraphs 1.3.15.)
10. The use of mirror surfaces as a means of identifying the existence of a series of cause and effect relationships between the sun and the kinetic activity of the sculpture (Mechanical, paragraphs 1.3.16.).

1.4.2. The Initial Conclusion suggest the work in this chapter can be summarised into two categories:

- (a) Devices which respond as a direct result of changes in solar activity - the Chemical and Mechanical areas.
- (b) Devices which exist as control mechanism and play an intermediary role between changes in solar phenomena and changes in the kinetic activity of a sculpture - Photoelectrical.

1.4.3. Photoelectrical devices do not fit into category 'a' because of the additional requirement of an electrical power source which, as far as this project is concerned, comes independently of the sun (see paragraph 1.2.1.). These switching devices, by responding to particular natural light thresholds, can be set to select and regulate kinetic activity in a sculpture by controlling electric motors, for instance. They avoid however, excursions into the areas of kinetic sculpture where a pre-programmed mechanism, rather than an external stimulus, causes the effect.

1.4.4. In the chemical and mechanical areas the response between sun and sculpture can be direct and require no additional power source. The effect of the sun and air currents on the piston or the three-component system can be continually modified, in many ways. In the case of the chemical system, this was achieved by varying proportions of each of the three chemicals, (see paragraph 1.1.5.). This enables reactions to occur at different temperatures. In the mechanical area, this can be obtained by a selection of gearing, or by varying the area and angle to the sun of the parabolic reflector.

1.4.5. In the mechanical area, an early possibility considered the use of the Sterling engine. This was not mentioned earlier since no practical work involving its use took place. The Sterling engine provides a power source which is uniform, to the extent that minor fluctuations in solar radiation are not reflected in its performance. This insensitivity is a major disadvantage, since it prohibits the making of a sculpture which can be seen to respond both sensitively and purposefully to minor fluctuations in solar radiation. In addition, there is the inevitable problem of sculpture plus engine; since the engine cannot be hidden. It is therefore, difficult to imagine how the two might be meaningfully integrated into a total unit, thus avoiding the dichotomy of sculpture plus engine.

1.4.6. From the conclusions to each of the three areas it was decided that the technical problems which have been observed in the

chemical area (loss of equilibrium, fading of dyes, see paragraph 1.1.23.) are such that a continuation of this area could result in a preoccupation with these problems.

1.4.7. It is fortunate that this area was the first to be investigated. The ease with which this three-component system could eventually be tuned to respond to changes in solar temperature made it a very rich and flexible area for experiment.

1.4.8. From the chemical area there also came the use of statistical information in conjunction with real conditions, as a theme for kinetic activity, and this was further developed in the photoelectrical area (see paragraph 1.2.6.). In the chemical area this theme led to the vitally important concept of movement and counter movement, (see paragraphs 1.1.19.).

1.4.9. In the mechanical area, wax-filled pistons were used to create movement. This movement which generated a series of configurations relating to seasonal variations, also formed a contrast to the abrupt response of the switching mechanisms studied in the photoelectrical area. The latter was partly due to the natural time delay of the piston, and also to the range of movements which the piston produced in the sculpture, (i.e. from staccato - legato, paragraph 1.3.15).

1.4.10. The observation in the mechanical area, that the sculpture mirrored in its reflective surfaces, the sun and its effect on the landscape was of extreme importance, (see paragraph 1.3.16.). This observation suggested that states of wholeness could exist, of which the sun, sculpture and observer are integral parts, (see paragraph 1.3.16.). Thus the observer could comprehend that changes in sunlight (the cause) are matched by actual movement in the sculpture (the effect). It therefore followed that if states of wholeness were to be respected, then a theme had to be established, in which the kinetic activity of the sculpture could be seen to be a simultaneous response to changes in sunlight. This theme would be

used to keep intact a direct visible link between sun and sculpture.

1.4.11. In the photoelectrical area, it was decided to restrict the spectral intensity measuring device to the visible region, in between the infra-red and ultra-violet wave bands, (see paragraphs 1.2.14-15). This decision now fitted in well with the theme of establishing a direct link between sun and sculpture, since it dismissed the idea of the sculpture responding to changes in sunlight which cannot be observed by the naked eye.

1.4.12. However, it was also realised that in the course of a day there may be sudden and complex events in solar activity, which may pass unnoticed by the observer. These events require magnification, through the expansion of their time duration, if they are to be fully comprehended. The frequency modulator (see paragraph 1.2.17.) which was originally brought into the range of devices to explore this possibility, was again used. But this time more detailed consideration was given to the legitimacy of time dilation.

1.4.13. From exploratory tests it was soon realised that the use of the frequency modulator must be restricted to the playing back of sudden changes in solar activity immediately after their occurrence. To avoid confusion, and preserve the direct link between sun, sculpture and observer, it was also realised that the kinetic activity which this device promoted would have to appear on a very different level to that normally associated with the apparent simultaneity of events.

1.4.14. As I worked on the sculpture in the mechanical area, I became very aware that aesthetically the photoelectrical area was the least developed. This was because research in the photoelectrical area had tended to concentrate on the construction of a much wider range of technical devices, than either the chemical or mechanical areas. There was an inherent danger in this, since the continued exploration of technical aspects, could result in the aesthetic priorities of the project being eclipsed.

1.4.15. This questioning of the photoelectrical area began to raise other points. For instance, was the frequency modulator really necessary? Is there not enough happening to the sun which can be comprehended by the observer in real time, without the magnification and sudden playback of sudden and complex events?

Chapter 2

Developments involving the integrated use of Chemical, Photoelectrical and Mechanical devices.

2.0.1. The research discussed in this chapter stems from a series of decisions dealing with the integrated use of the three systems dealt with in the previous chapter. The research was developed with the intention of making, -

- (a) A general contribution to the subject, in the sense that many of the developments could form departure points for future research, involving the development of kinetic sculpture by the utilization of solar energy.
- (b) A specific contribution to this particular project through the extension of some of the developments into maquettes, and perhaps, sculptures.

2.0.2. The developments in this chapter are discussed chronologically, and deal with the following combinations,-

- (1) Chemical/Photoelectrical, (The juxtaposition of temperature with light).
- (2) Mechanical/Chemical. (The juxtaposition of temperature sensitive mechanisms with different technological bases).
- (3) Mechanical/Photoelectrical. (The juxtaposition of temperature with light).
- (4) Additional Developments. (Involving the translation of changes in the light and heat from the sun into sound and movement).

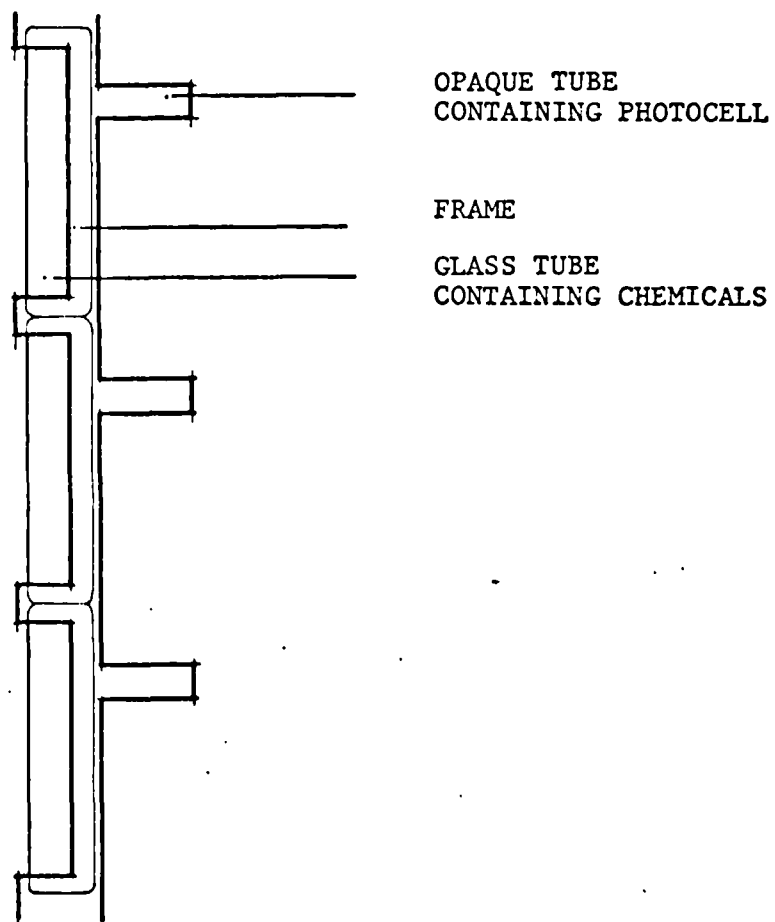
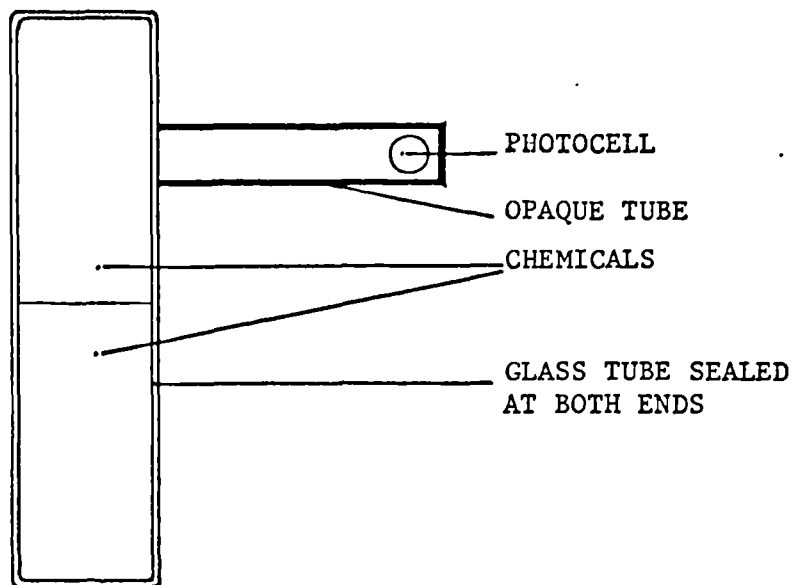
Chemical/Photoelectrical Area

2.1.1. The drawing at the top of page 66 represents a glass tube, internal diameter 40 mms., length 140 mms., which is filled with chosen proportions of methanol, octane and carbon tetrachloride. At the mid-point of the upper half of the glass tube is an opaque tube, internal diameter 15 mms., length 120 mms. One end of this tube is glued to the glass and the joint is made light proof. At the opposite end of this tube is an O.R.P. 12 photocell, with its aperture directed towards the chemicals. The wires to the photocell pass out through the end of the tube, behind the aperture of the photocell. These wires then travel to a 12 volt relay switch which is operated by the photocell.

2.1.2. To proportions of 3.85 methanol and 4.50 octane were added the following amounts of carbon tetrachloride - 2.13 (inversion at 3°C), 1.92 (inversion at 10°C) and 1.83 (inversion at 16°C). To each of the portions of methanol was added methyl violet, until the methanol became opaque, the octane remaining transparent. To assist the observations, a six volt electric light bulb and power supply was connected to the twelve volt relay.

2.1.3. By reference to Meteorological Office information ⁽³⁷⁾ a variety of daily temperature cycles were simulated with the result that inversion occurred at the anticipated temperatures. It was found that before inversion, when the transparent octane was at the top of the tube, the light bulb was activated. Alternatively, when inversion had occurred and the methanol was in the upper half of the tube, the light was inactive. This much was anticipated before the experiments commenced.

2.1.4. Inversion does not take place abruptly, unless there is a very sudden and extreme change in temperature. Instead, there is a gradual visual intertwining of the liquids, in which their viscous properties are emphasised. This is particularly evident when one of the chemicals is coloured. This property of the system



DRAWINGS OF TWO CHEMICAL/PHOTOELECTRICAL DEVICES.

led to the light bulb being triggered on and off at intervals of decreasing length until the inversion phase was completed.

2.1.5. A further experiment took place as a result of this latter observation. In this experiment, the inside of the tube containing the photocell was given a polished surface. This surface magnified the commencement of the inversion phase, and caused the electric light bulb to be triggered even more frequently.

2.1.6. A further scheme (which remains unconstructed) is shown on the bottom half of page 66 . It consists of a stack of differently tuned chemical/photoelectrical devices, of a similar size to those used in the previous experiments. These would be held in position by a frame, consisting of a mild steel tube, with the appropriate sections cut out to accommodate the separate tubes of chemicals. The tubes containing the photocells would be welded to this metal frame.

Initial Conclusions to the Chemical/Photoelectrical Area

2.1.7. Observations suggest that these chemical/photoelectrical devices have some very specific possibilities as control mechanisms, for translating the behaviour of the three component chemical system into another medium. This could be a colour, or light switching mechanism, (as in the experiments) or possibly a device for controlling actual movement, through the use of an electric motor.

2.1.8. The problems experienced earlier in the chemical area, such as loss of equilibrium and the fading of dyes, (see paragraphs 1.1.23. - 24.) could be counteracted in these chemical/photoelectrical devices by changing the chemicals regularly. This would be viable, both practically and economically, since as control mechanisms, these devices need only be built to the specified size.

Mechanical/Chemical Area

2.2.1. Work in this area commenced by examining how the problem of loss of equilibrium in the chemical area might be overcome. This led to the development of two devices which could periodically agitate the chemicals by sudden movement, or extremes of temperature.

2.2.2. The first device, shown in the drawing on page 69, was concerned with agitation by sudden movement. It comprises a one metre length of 22 gauge piano wire, cut approximately 19 cms. from one end. The two pieces of piano wire each have one end attached to a wire cradle which contains a glass tube of the three-component chemical system. The shorter piece of wire is attached to a fixed point above the cradle, the longer length of wire to a variety of springs selected from the Springmaster range.

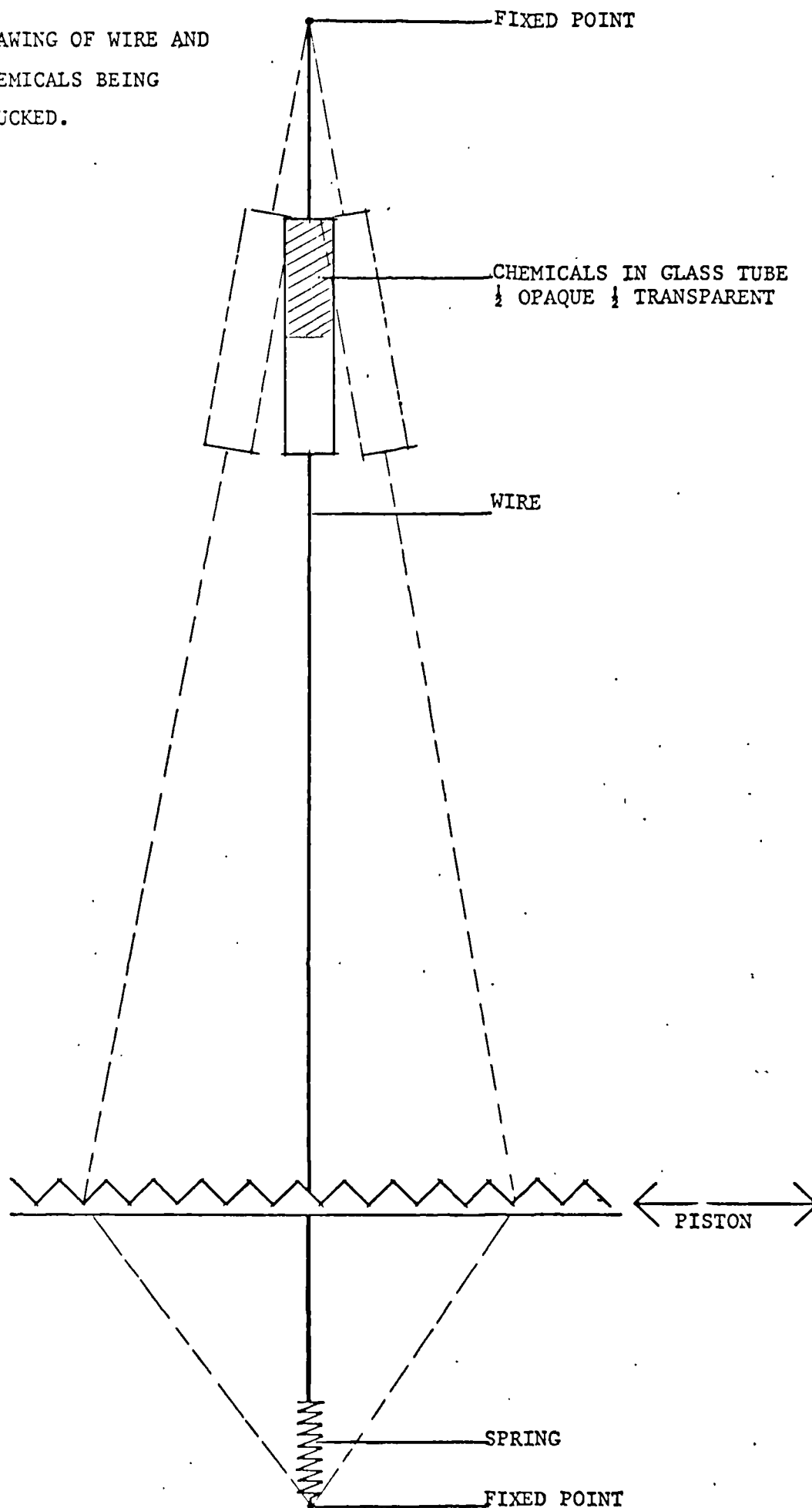
2.2.3. The piano wire was plucked by a type of rack, moved to and fro by a piston mounted over a parabolic reflector. Both the piston and the reflector were of the type used in the mechanical area, see paragraphs 1.3.1-2).

2.2.4. The three-component system was tuned to invert at temperatures between 4° - 10°C . To assist observations the methanol was coloured with waxoline dyes. In addition, the bottom half of the glass tube containing the chemicals was opaque, therefore colour was evident only before inversion.

2.2.5. The first type of rack to be used was a Meccano toothed plate. This was found to be too fine as it hardly vibrated the wire. It was therefore replaced by hard, medium and soft-plectrums, which were secured to a metal bar. The bar, which slid between keepers, was moved by having one end fastened to the push rod of the piston.

2.2.6. This device was tested outside through the months of February and March 1977. During this eight week period, the intermittent plucking motions were sufficient to cause the chemical

DRAWING OF WIRE AND
CHEMICALS BEING
PLUCKED.



system to maintain a state of equilibrium. It was also found that the longest duration of perturbations occurred when the piano wire was held taut by a $1\frac{1}{2}$ " spring and plucked with a hard plectrum. The plucking also produced a note which along with the frequency and duration of the perturbations, could be controlled by,

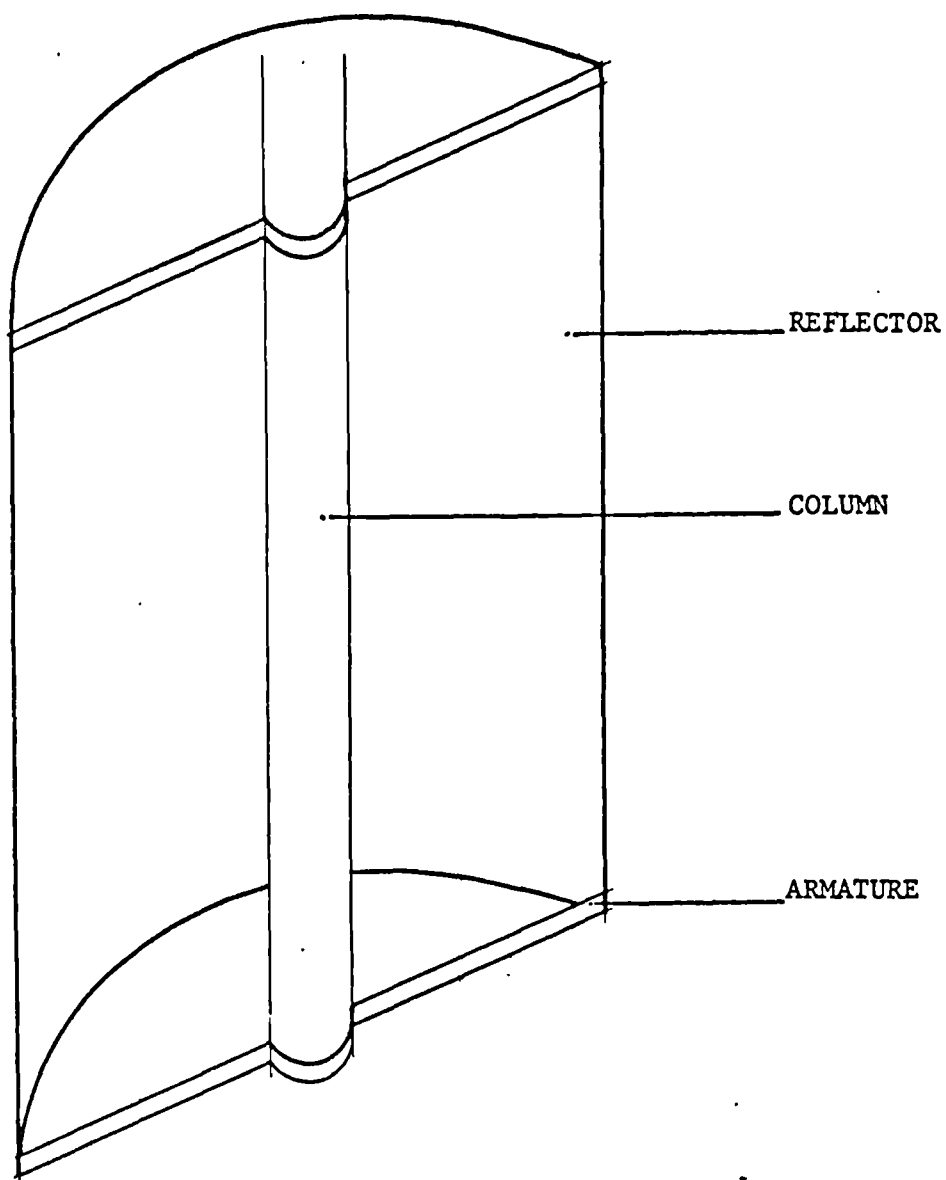
- (a) The tension of the spring
- (b) The type of plectrum

2.2.7. Experiments continued, in which wires and chemicals were grouped in 3' high rows. To avoid damage the chemicals were suspended at different heights. Each of these groupings led to problems in the relationship between the chemicals in the tubes and the perturbations of the wire. For practical reasons, the wires and the glass tubes of chemicals could not be packed close enough to define either a plane or a volume. The definition of a plane or volume required the work to be constructed to at least three times its original size. Naturally, this would cause additional problems connected with the ability of the piston to drive a piece of work of this size and type.

2.2.8. The second device in this area was concerned with agitating the chemicals by subjecting them to extremes of temperature. This initial scheme is shown on page 71 . It consists of a parabolic reflector which has at its focal point, a column containing one, or a number of the three-component chemical systems. The column is constructed so that the coloured methanol is visible after inversion.

2.2.9. At first, it was decided to place these reflectors at specific angles and points to the sun's daily and seasonal path. By so doing, the chemicals could each be in the direct rays of the sun at a particular time of the day and year.

2.2.10. This scheme was investigated during February and March 1977, and inversion took place frequently. It was noticed that during the inversion phase, when the colours in the central column



DRAWING OF MECHANICAL/CHEMICAL DEVICE.

became visible, their presence was made all the more apparent by their reflections in the parabolic reflectors.

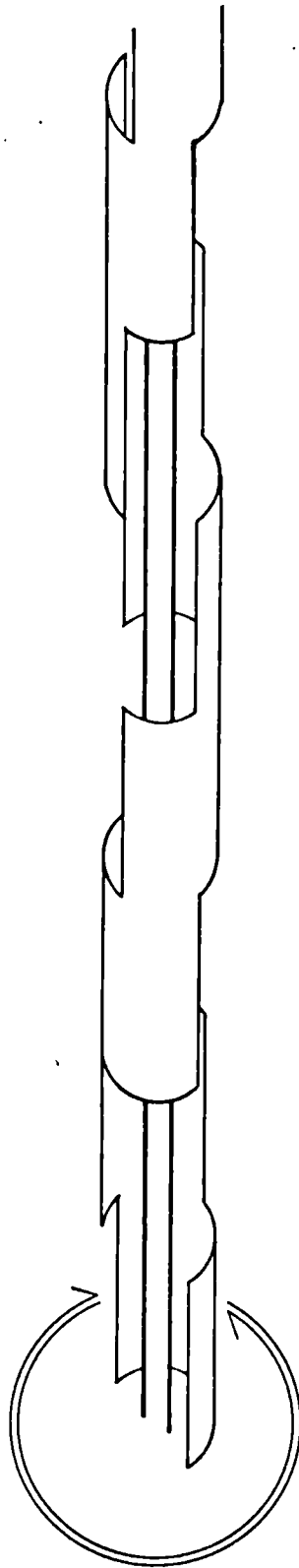
2.2.11. As work continued on this device it was realised that the addition of a heat sensitive piston, to the previous combination of reflector and central column of chemicals, could produce almost continual movement.

2.2.12. A scheme involving the use of pistons was developed as a very elementary maquette. This is shown on page 73, and consists of a central column encircled by reflectors. The reflectors are stacked on top of one another at 90° intervals and are attached to the central column, as described in the drawing on page 71. They are rotated by two pistons, positioned at the focal point of the two lowest reflectors.

2.2.13. The central column houses seven, three-component chemical systems, which are stacked on top of one another. Due to the range of temperatures experienced during February and March, two of the three-component chemical systems were tuned to invert at 11°C , two at 12°C , two at 13°C , and one at 14°C . (See paragraph 1.1.5., for the proportions). To assist observation, the methanol was coloured with methyl violet.

2.2.14. This scheme was realised as a very elementary maquette, in which the performance of the pistons rotating the reflectors was simulated by hand. It was known from the previous monitoring of these pistons, (see appendix, section 5) that on a clear day the pistons would cause the reflectors to rotate at sunrise, the movement gradually decreasing towards mid-day. After mid-day, there would be a gradual increase in movement towards sunset. Intermittent gusts of cool wind, or passages of cloud naturally upset this trend.

2.2.15. It was found that inversion sequences in each of the chemicals usually occurred when the reflectors turned to focus the sun's radiation on the chemicals. Often, one of the chemical



DRAWING OF PARABOLIC TOWER DRIVEN BY PISTON.

systems would commence its inversion phase, only to be abruptly interrupted by the reflector changing its position. This halted the inversion phase. Alternatively, prolonged focussing of the sun's rays on the chemicals, occasionally induced them to reach single phase. Repeated tests also showed that the extremes of temperature achieved with the parabolic reflectors, kept the chemicals in equilibrium.

2.2.16. During the experiments with the reflectors and the three-component chemical system, work was also taking place on the development of gearing systems which would enable the piston to rotate the tower of reflectors. A mechanical system was first developed, this was difficult to construct and it also lacked the required sensitivity. An alternative was the development of a mechanical/electrical servo system, in which the displacement of the piston could control the movement of an electric motor, (see appendix, No.7, for circuit diagram). A six volt Monoperm motor was finally selected, with the full gearbox this delivered 20 R.P.M. The motor was further geared down mechanically to 10 R.P.M., which appeared to be the speed required.

2.2.17. It will be noticed from the circuit diagram, that the response of the motor to the displacement of the piston, can be altered by adjusting the gain control. This is an advantage over a purely mechanical system, since it is much simpler than having to change gears, pulleys and belts etc. Consequently a displacement by the piston of, for instance, 6 mms., can be readily converted into several revolutions by the motor. To avoid the motor hunting, the gain control was adjusted to well below this threshold; thus a 2 mms. displacement by the piston, caused the motor to turn through approximately one revolution.

2.2.18. After the development of the servo system, work ceased on the chemical/mechanical maquette. In view of the problems already experienced in the chemical area (see paragraph 1.1.23.), it was considered to be inadvisable to continue the construction of a full size working maquette until a more colour fast range of dyes had been found.

Initial Conclusions to the Mechanical/Chemical Area

2.2.19. Experiments have shown that the problems experienced in the Chemical area, relating to loss of equilibrium, (see paragraph 1.1.23.) can be overcome by:-

- (a) Periodic agitation, caused by a piston plucking a wire, to which a tube containing the chemicals is attached. This also led to movements which produced sounds.
- (b) Periodic exposures to extremes of temperature, by using a piston to intermittently rotate parabolic reflectors around a column containing chemicals.

These points have alleviated one problem, but no means has yet been found of overcoming the fading of the Waxoline dyes.

2.2.20. An additional development from this mechanical/chemical area, has been the construction of an electrical servo system to assist the performance of the piston. This development has the advantage of :-

- (a) Making the performance of the piston extremely sensitive.
- (b) The range of movement of the piston can be increased or reduced, in seconds, by altering the gain control of the servo system.

Mechanical/Photoelectrical Area

2.3.1. The first device to be considered is shown diagrammatically at the top of page 77 . It consists of a piston moving a segment of a circle. Near the perimeter of this segment are situated a sequence of coloured gels, ranging from an aesthetically hot colour temperature at one end, to cold at the other. Beneath the coloured gels is a fixed light source which shines through a restricted section of the sequence of gels.

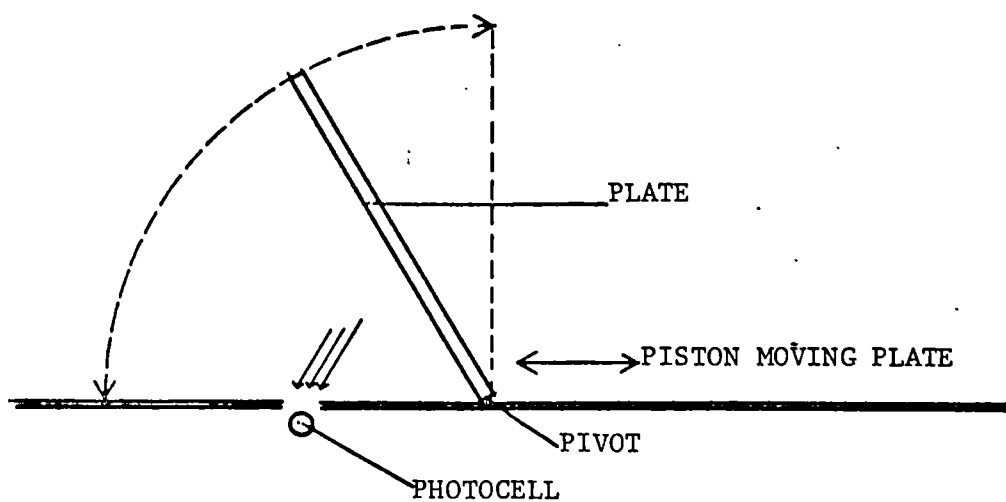
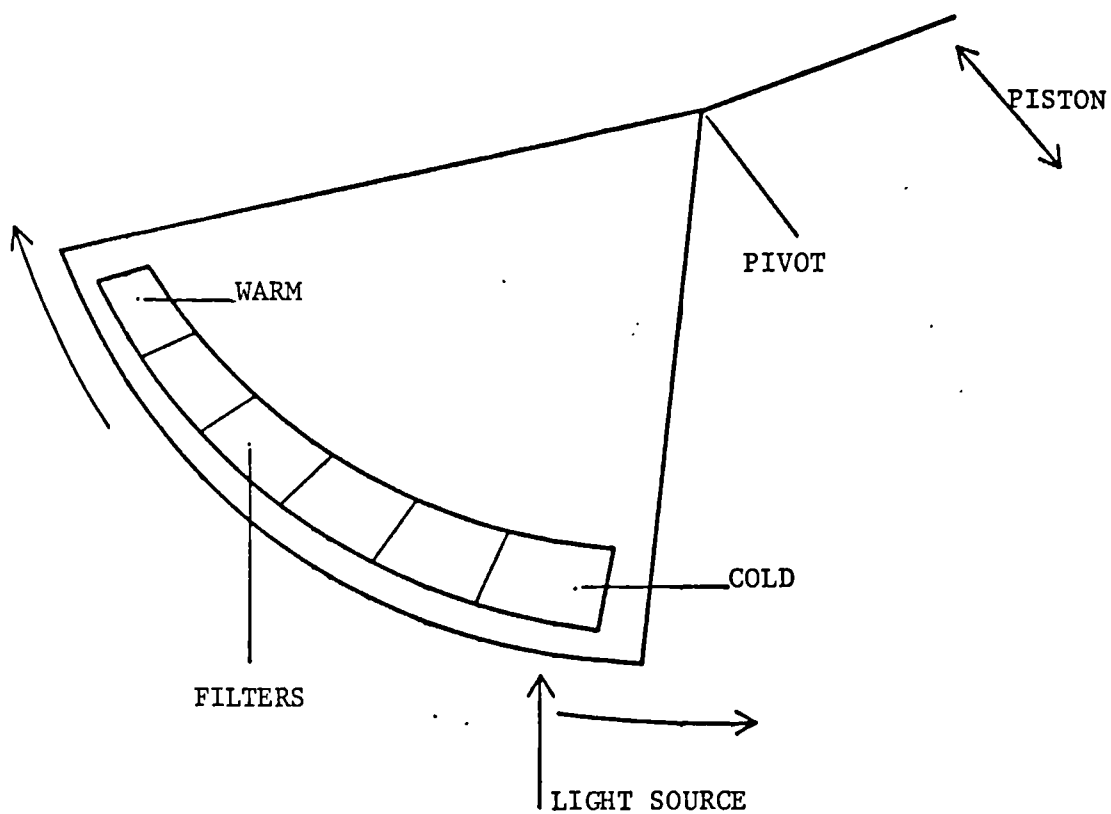
2.3.2. This device is essentially a control mechanism which, according to how the coloured gels are placed, changes from cool to warm colour as the temperature increases and the piston expands, (image by similarity). Alternatively, the sequence from hot to cold colour could be reversed. In this case an increase in temperature would lead to the predominance of the cool section of the spectrum, (image by contrast).

2.3.3. Another development of this scheme might be to replace the coloured gels with either, (a) Kodak Neutral Density Filters or, (b) Kodak Wratten (coloured) filters. In addition, the light source below the filters could be replaced by a photocell, (this would make the device truly photoelectrical) which would receive illumination from sunlight penetrating the filters above.

This would lead to-

- (a) The level of illumination falling on the photocell being selected by the temperature.
- (b) The wave length of light falling on the photocell being selected by the temperature.

2.3.4. A second scheme, which is shown in the diagram at the bottom of page 77, was also concerned with the movement of a piston changing the illumination of a photocell. In this scheme a piston



DRAWINGS OF TWO MECHANICAL/PHOTOELECTRICAL DEVICES.

moved a mild steel or Perspex plate, hinged at its base, through 90° . In so doing it changed the level of illumination of a photocell, the aperture of which was directed towards the plate.

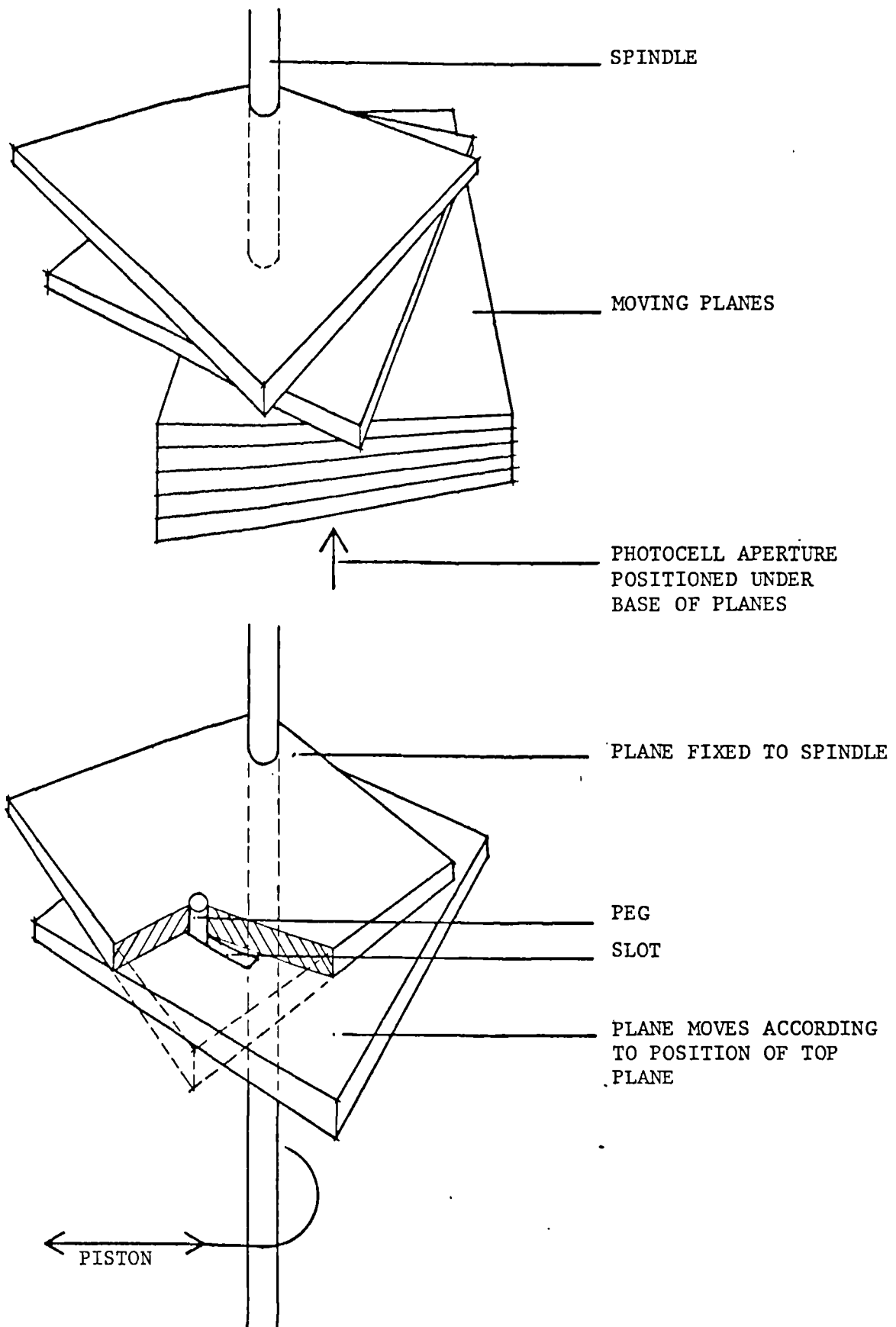
2.3.5. Depending upon the position of the sun, relative to that of the plate, the resistance of the photocell was changed by either -

- (a) Direct light falling on the photocell, (in which case the plate may not affect the resistance of the photocell).
- (b) Reflected light from the plate.
- (c) Cast shadows from the plate.

2.3.6. To increase certain reflective properties of the plate, the surface was subsequently ground in various directions with a fine sanding disc, and protected against oxidisation by the application of a high grade polyurethane lacquer. This achieved an extensive scatter of reflected light which caused wider and more frequent variations in the resistance of the photocell. At this point work on the device ceased and it remains as a very sensitive control mechanism.

2.3.7. A further device constructed in this mechanical/ photoelectrical area is represented in the diagrams on page 79. It consists of a piston, which rotates rectangles of smoky grey Perspex. Below the Perspex rectangles is a photocell, the light source of which is controlled by the movement of the rectangles. Used in this way the perspex rectangles become a stack of filters.

2.3.8. The piston rotates the Perspex rectangles as follows. There is a simple rack and pinion drive from the piston to a spindle. This spindle rotates inside a sleeved tube which is fixed at the base. As the spindle is rotated it moves the topmost rectangle which is fixed to it. As this topmost rectangle is rotated, a peg on its underside slides in a slot in the rectangle below. When the peg has reached either end of this slot it engages the rectangle



DRAWING OF MECHANICAL/PHOTOELECTRICAL FILTER SYSTEM.

below, which is free. As the topmost rectangle continues to rotate it sets up a chain reaction, which eventually causes all of the rectangles to move.

2.3.9. The outcome of this filter system of Perspex rectangles was that the aesthetic framework for a sculpture was produced, in which rectangles twisted and spiralled about a column in response to changes in temperature.

Initial Conclusions the the Mechanical/Photoelectrical Area

2.3.10. Experiments in this area have been concerned with three devices, each of which consist of a photocell (light), the resistance of which is altered by the movement of a piston (temperature).

2.3.11. The first device to be tested (see page 77 , top) comprised of a range of gels, which were propelled above an artificial light source by a piston. In later developments, this light source was replaced by a photocell. Light fell on this through the filters above.

Two types of filters were used.

- (a) Kodak Neutral Density filters
- (b) Kodak Wratten filters

This device remains a control mechanism, it has not been developed as, or incorporated in, a sculpture.

2.3.12. The second device consisted of a mild steel or Perspex

plate (see page 77 , bottom diagram) moved through 90° by a piston. The aperture of a photocell was focussed on this plate. As the piston moved the plate, the resistance of the photocell changed. In this context it was a control mechanism.

2.3.13. Aesthetically, this device has possibilities which suggest it could become something more than a control mechanism. These possibilities are connected with the way changes in sunlight, which cause the mild steel plate to move, are reflected in its surface quality. In this, the device demonstrates a similar range of aesthetic cause and effect relationships to those already discussed in the mechanically operated slate and stainless steel sculpture. (see paragraph no. 1.3.16.)

2.3.14. A further development which was considered, was the addition of a damper. This damper would be controlled by a photocell, and would cover the piston at particular illumination thresholds. A self regulating system such as this, could enable the movement of the plate to become more varied.

2.3.15. The third device, in which a piston rotated Perspex filters over a photocell (see diagram page 79), existed primarily as a control mechanism. At a later stage a maquette was developed. In this, the piston was replaced by a six volt motor, and the latter was controlled by a photocell in the base.

2.3.16. Unfortunately, severe practical problems have been experienced; the surface of the Perspex became scratched and abrasive. This was caused by the faces of the Perspex rectangles sliding over one another. Apart from creating aesthetic problems connected with the dulling of the Perspex, the main technical drawback was concerned with illumination thresholds. Through being scratched, the surface of the Perspex became more opaque. Consequently, over a period of weeks, the illumination penetrating the photocell, through an identical configuration of the Perspex rectangles, was reduced. Therefore the response of the maquette to specific

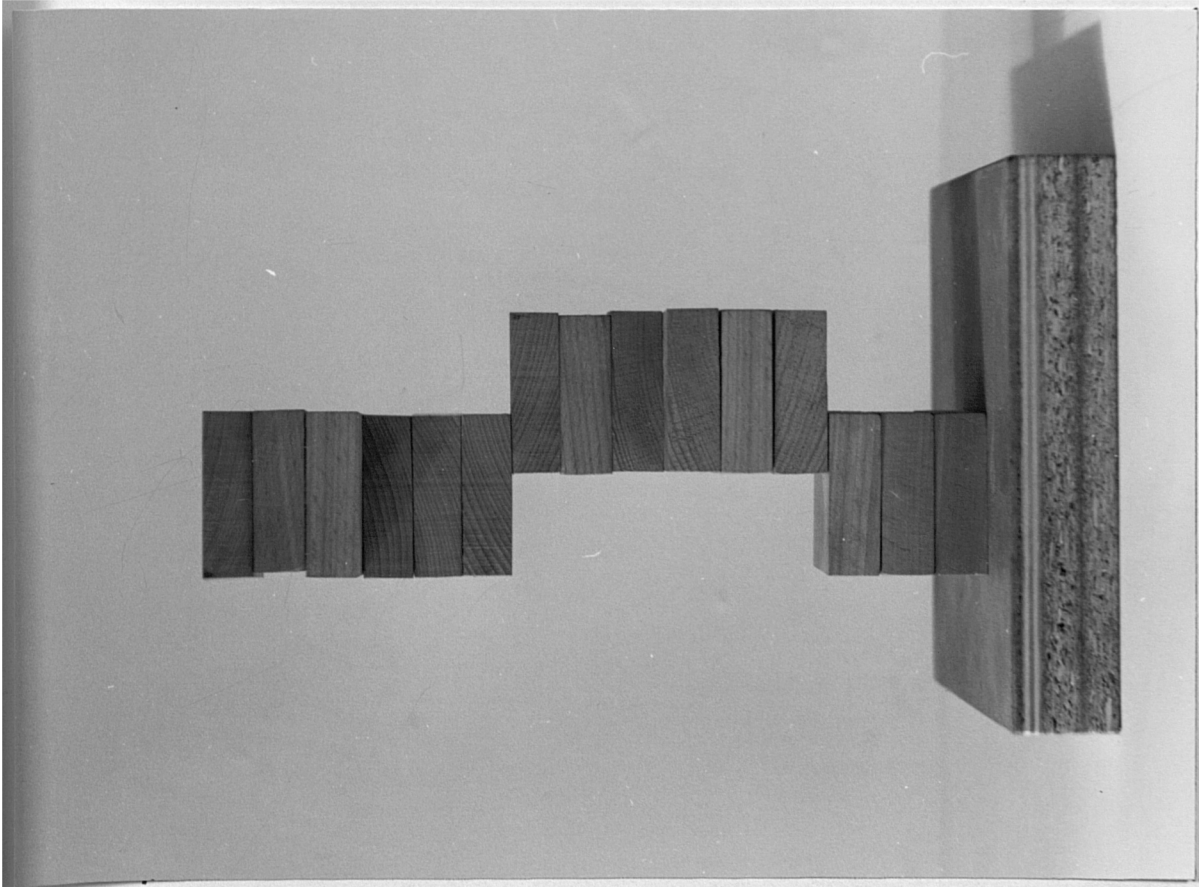
illumination thresholds became unreliable.

2.3.17. Another possibility concerning the disposition of rectangles about a common spine was considered. This is shown in the photographs on page 83 and involves two maquettes made up of equal numbers of identical rectangles. One of these maquettes would be preprogrammed, and respond to statistically predicted illumination levels for a given period. The other maquette would respond to the actual illumination levels for that period.

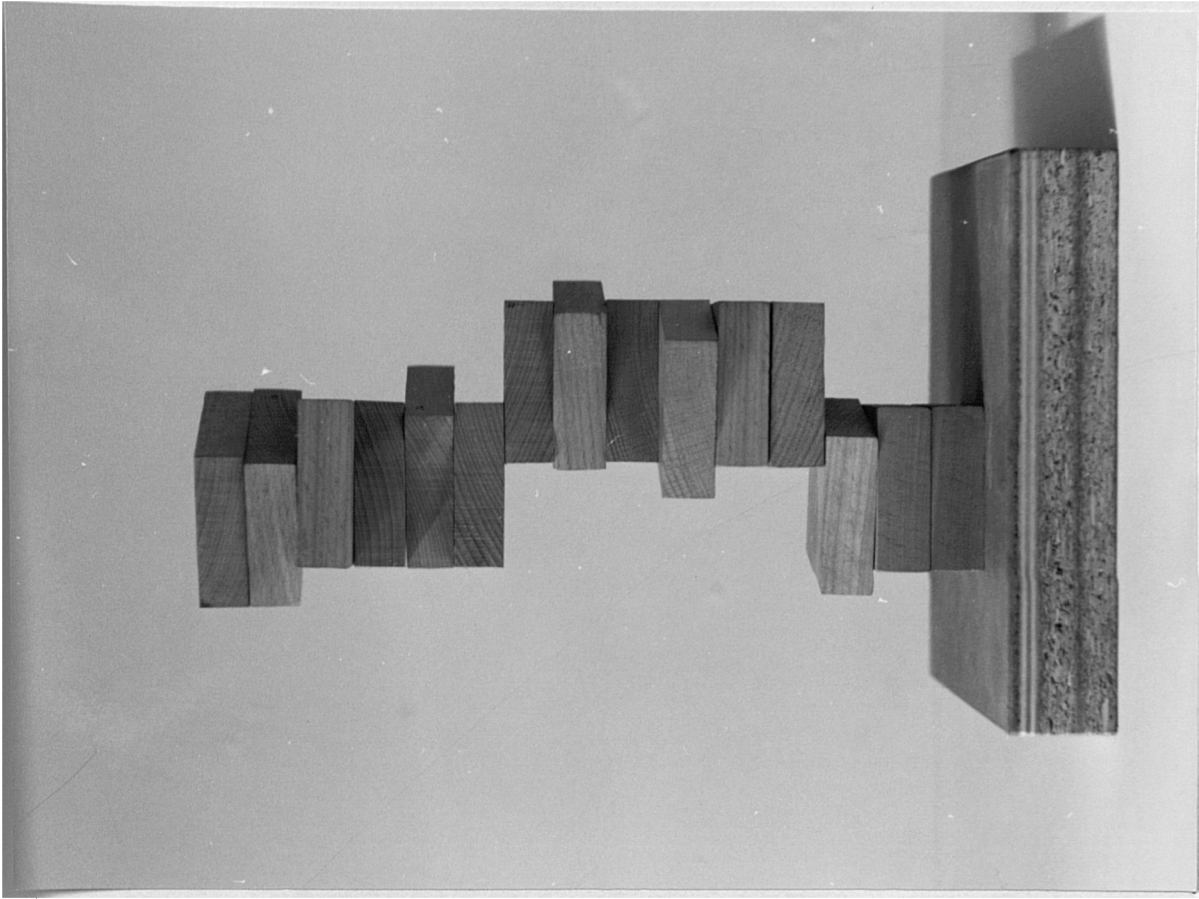
2.3.18. In the preprogrammed maquette the rectangles would move through a sequence of configurations, each relating to a particular climatic period or event. A column or helix could be used for the equinox for instance, or sets of cubic relationships for the solstices.

2.3.19. The maquette which responded to the actual illumination levels would be exhibited alongside the preprogrammed maquette. If the actual illumination was identical to that predicted in the preprogrammed sculpture, the sculptures would exhibit identical configurations. Alternatively, these configurations would differ according to variations between actual and predicted illumination levels. This could lead the observer to make visual comparisons between the proximity of actual to predicted climatic conditions.

2.3.20. The concept behind these sculptures was prompted by the way nature can chart its response to climatic variations. For instance, annual growth rings can give clues to the response of a tree to abnormal seasonal variations.



PRE-PROGRAMMED RESPONSE



ACTUAL RESPONSE

Additional Developments

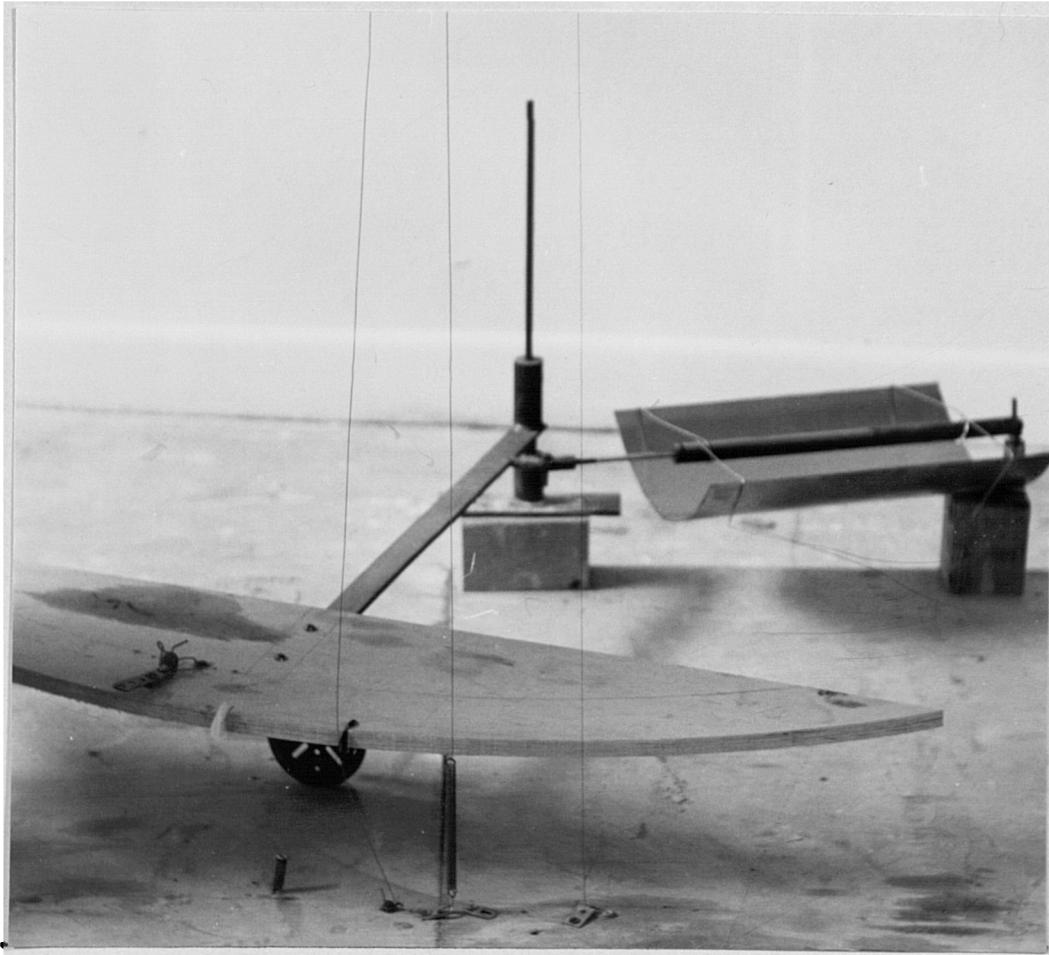
2.4.1. In the opening section of this chapter, the possibility of transposing changes in the light and heat from the sun into sound and movement, was mentioned. In the chemical/mechanical area experiments took place in which a piston plucked piano wires. These piano wires vibrated a selection of the three-component chemical systems and this enabled the chemical systems to maintain a state of equilibrium, (see paragraph 2.2.2.). However, it was also observed that the plucking of the piano wires produced a range of sounds which could be controlled by,

- (a) The tension of the piano wire.
- (b) The choice of plectrum, i.e. hard, medium or soft.

2.4.2. In the same section a servo system was developed which enabled minor movements of the piston to be amplified, (see paragraphs 2.2.16 - 17) I realised that with the combination of piano wire, piston and servo system, sound could be produced with very minor changes in solar radiation.

2.4.3. At the same time I became interested in the contradictory possibilities of this sound system. For instance, when exhibited outside, one might expect that sound was produced by air currents reverberating the piano wires. This would be the case with an Aeolian harp. Yet with this sound system it could become apparent, that sound was produced when there was no wind, and no sound was produced when there was wind.

2.4.4. Work on this sculpture commenced by experimenting with a selection of springs, piano wires and plectrums. These experiments were assisted by the construction of the frame shown on page 85. This consists of a wooden frame, with piano wire stretched vertically between the top and bottom sections to form a curved plane. In some cases springs were secured to both ends of the piano wire. The wires were plucked with plectrums, the latter fitting into the circular



PISTON OPERATED DEVICE USED IN PLUCKING PIANO WIRES.

wooden plate. This plate was pivoted at its centre and could be moved by a piston, or by hand.

2.4.5. A range of piano wire from 16-22 gauge was used, in lengths of approximately three feet. The springs were selected from a variety of sources. From this assortment of springs and wire, experiments showed the combination of a 1" Meccano spring at the top of a three foot length of 22 gauge wire, with a 3" long x $\frac{1}{4}$ " diameter Clerkes spring at the bottom to be the most successful. When plucked with a hard plectrum, this produced a light and audible note. The perturbations were clearly visible, often lasting for a minute's duration.

2.4.6. The tension of the piano wires also enabled the hard plectrums to gather up the wires and release these one by one, or in groups. This caused passages of distortion which radically altered the physical and perceptual nature of the curved plane of wires. This is shown schematically in the diagram on page 87. Drawing A, shows the plane of wires undistorted, B shows intermittent distortion, whilst drawing C shows the maximum degree of distortion available to this system.

2.4.7. As a result of the previous experiments, I began to realise that by expressing the wires as a volume defining configuration and not a plane, it would be possible to emphasise more their inherent transient visual qualities. This, I also realised, might eventually be assisted by the construction of a sculpture which was not subject to the visual encumbrances of a heavy frame.

2.4.8. This intention led to the construction of the maquette, shown on page 88, in which three foot lengths of piano wire define the spatial volume of a cylinder. A circular plate driven by a piston revolves inside this cylinder of piano wires. Radiating from the centre of this circular disc, are a series of spring loaded plectrums which were constructed to emphasise the plucking motions. These are shown in the photograph on page 89. The spring loaded

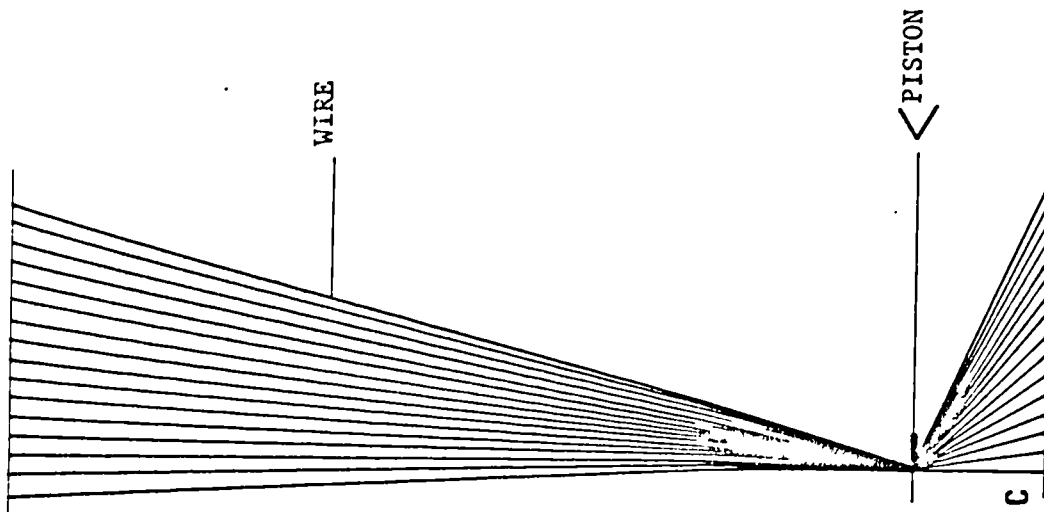
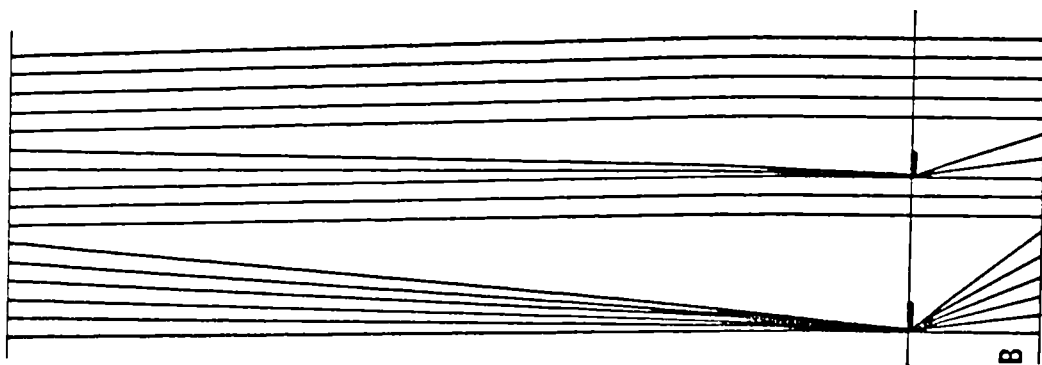
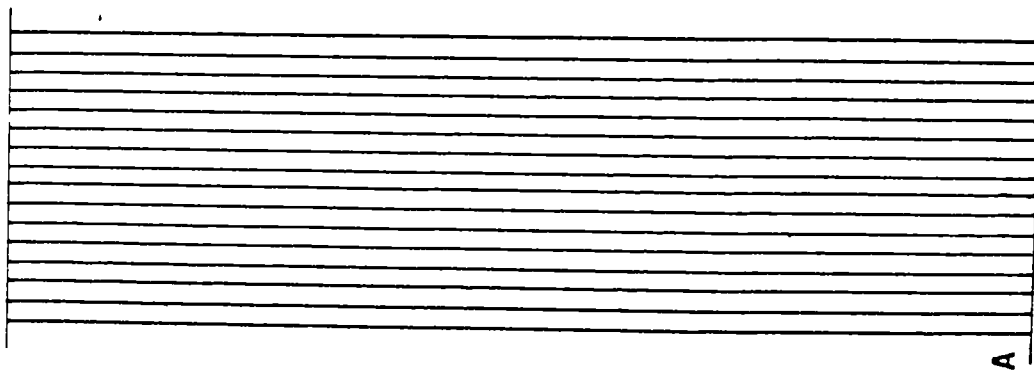
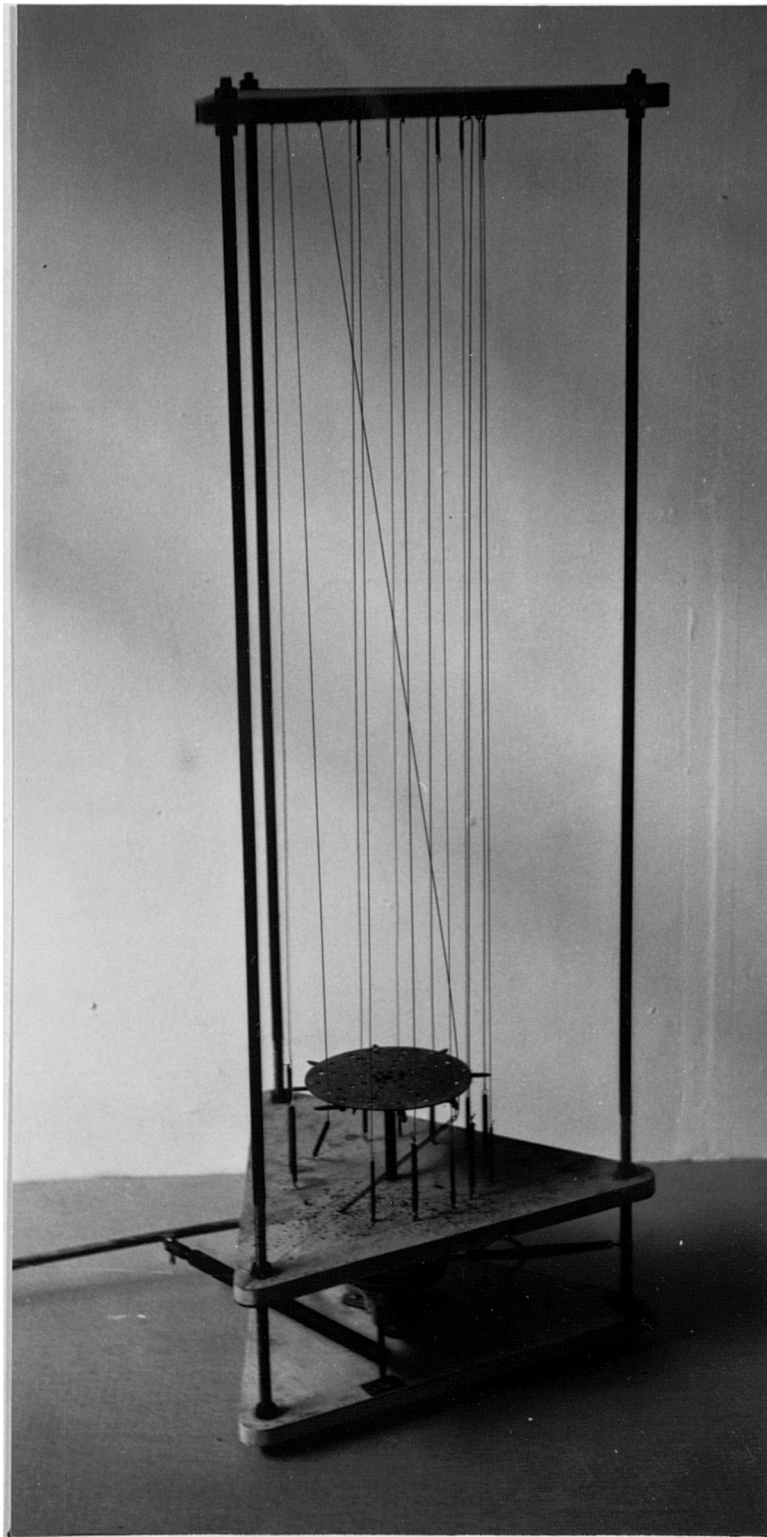
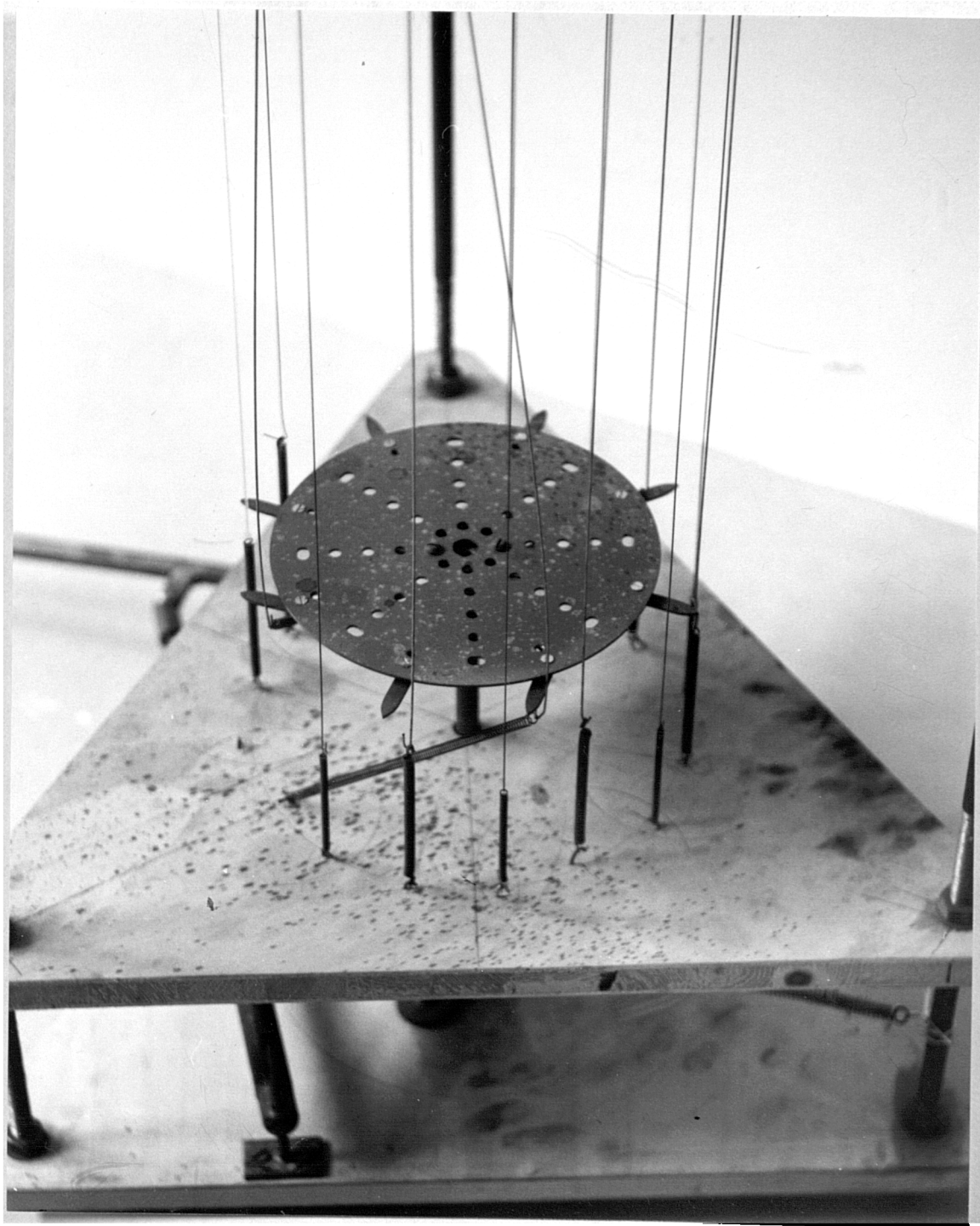


DIAGRAM SHOWING THREE POSSIBLE WIRE CONFIGURATIONS.



PISTON OPERATED DEVICE USED IN PLUCKING PIANO
WIRES. HEIGHT 3' 9".



VIEW OF BASE, SHOWING REVOLVING DISC AND SPRING LOADED PLECTRUMS.

plectrums did emphasise the plucking motions, but in doing so they detracted from the distortions they caused to the cylinder of wires. In addition, these spring loaded plectrums added nothing to the sound quality of the maquette.

2.4.9. From this maquette, I realised that much of the technology had to be buried, and I had to concentrate on exhibiting the transient audio-visual qualities of the wires. As far as the piston was concerned there was no problem, for it could be situated some distance away from the sculpture and drive it remotely through the servo-system. The plectrums, which in the previous maquette had posed visual problems, could be hidden in the base, along with the servo-system and power supply. In the previous maquette the frame had been reduced to three $\frac{1}{2}$ " round, mild steel rods, kept in position by three triangular wooden plates. Yet this still had an uncomfortable dominance and had to be removed or become transparent.

2.4.10. The idea of the frame becoming transparent led me to consider the possibilities of Perspex and glass, as an alternative to the mild steel rods. Elementary maquettes were constructed to explore this alternative and I realised that perhaps instead of using the frame as a supporting mechanism for the wires, it might be an advantage to aim for a total integration. This could also enable the frame to emphasise, possibly through reflection, the wires as they defined a spatial volume.

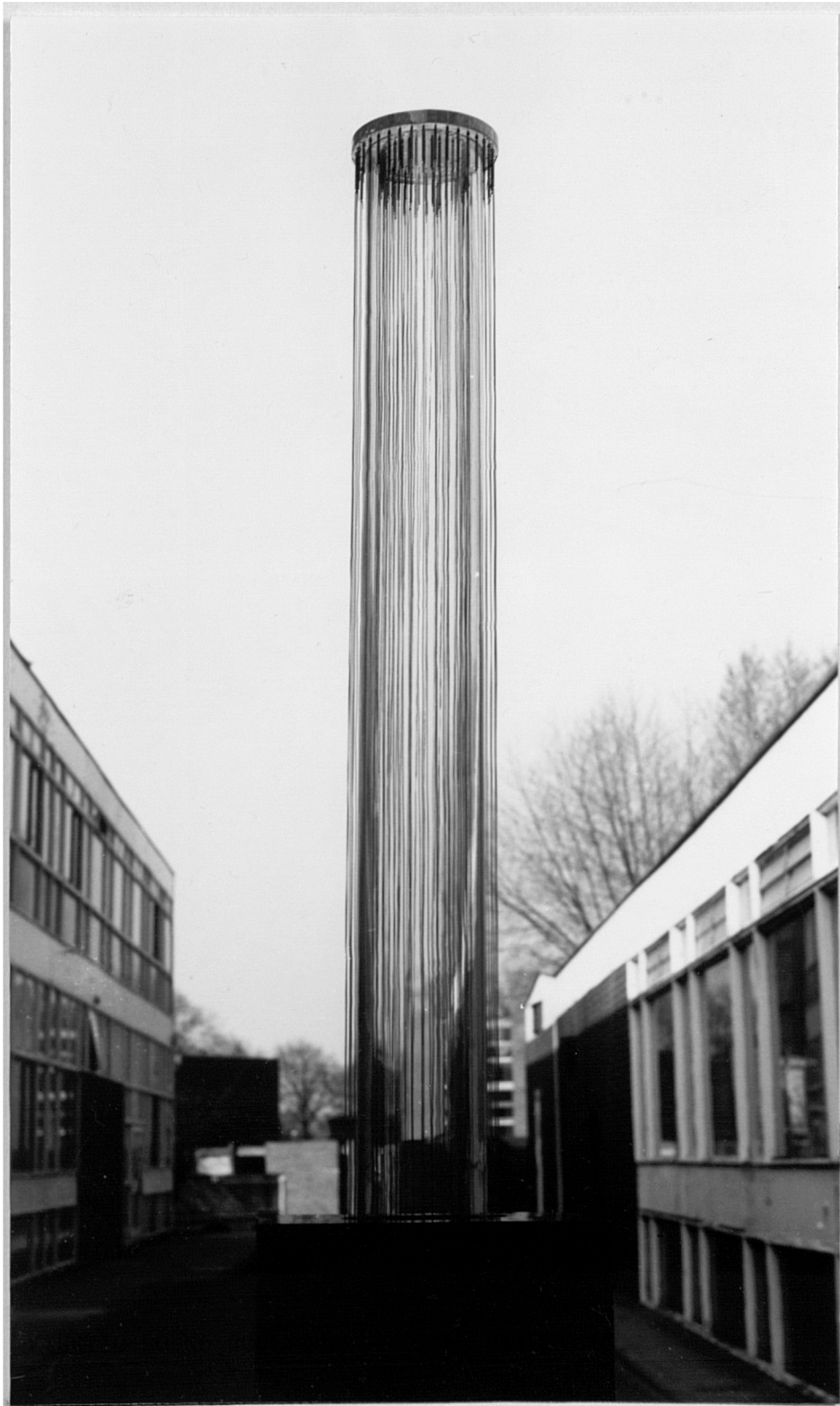
2.4.11. Further developments ensued, in which the piano wires were arranged around a selection of transparent Perspex tubes. As in the previous maquette, 22 gauge piano wire was used in three foot lengths. These had 1" long Meccano springs attached to the top, and 3" long x $\frac{1}{4}$ " diameter Clerkes springs at the bottom. The wires and springs were arranged at 10° intervals, $\frac{1}{4}$ " away from the outside wall of a 3' 6" long x 4" diameter Perspex tube. This arrangement produced a visual density where the wires (not the Perspex) defined the spatial volume of a cylinder. The effect was heightened by the reflection of the wires in the tube.

2.4.12. However, I was uneasy with the way natural light sometimes emphasised the internal dimensions of the Perspex. This emphasis was eventually counteracted by arranging the same combination of piano wires and springs $\frac{1}{4}$ " away from the internal face of the Perspex.

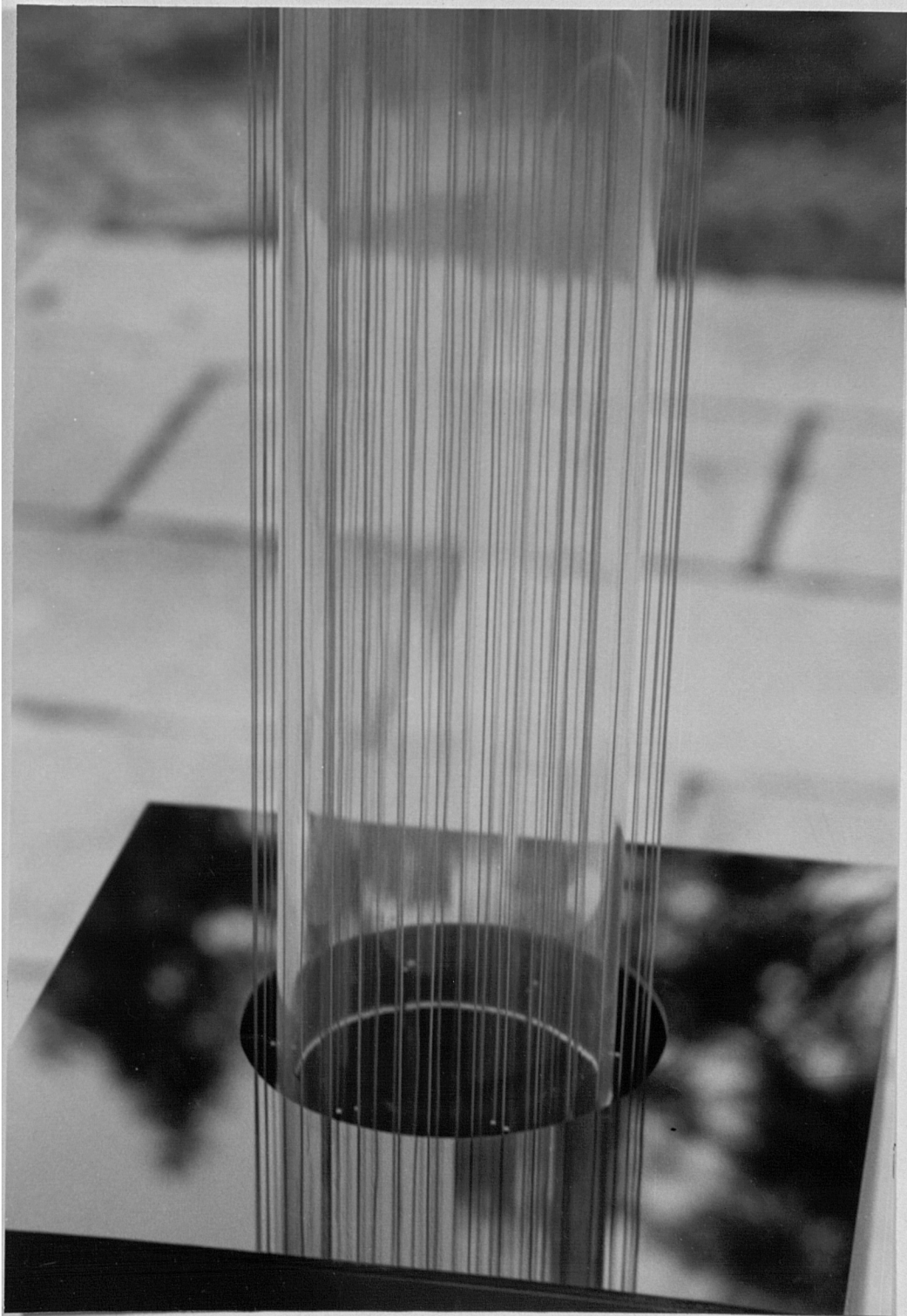
2.4.13. Finally a sculpture measuring seven feet in height was constructed; the upper portion consists of the cylinder of Perspex, piano wire and springs. This sculpture is shown on pages 92 - 93 . The cylinder is rotated by a six volt Monoperm motor, which is controlled remotely by the piston and accompanying servo-system. An expansion of the piston causes the cylinder to revolve clockwise, whilst a contraction causes it to revolve in an anti-clockwise direction.

2.4.14. As the cylinder rotates it is plucked internally and externally with hard plectrums which are mounted in the base 3" above the ends of the piano wire. These plectrums are positioned at 0° , 80° , 170° , 230° and 300° around both the interior and exterior of the tube. This irregular positioning causes unequal passages of distortion as the plectrums gather up and release the strings of the revolving tube.

2.4.15. Originally it was decided to use glass instead of Perspex for the revolving cylinder, since glass is more durable and easier to clean. Unfortunately, during the period when this sculpture was constructed glass cylinders of the dimensions required were unavailable, and time was limited. It was therefore decided to construct this sculpture more as a working mock-up: Should a situation arise where it was to be exhibited outside on a permanent basis, then such materials as the Perspex cylinder and wooden base would be replaced by glass and mild steel respectively. In addition, more watertight bearings would be introduced between the revolving cylinder and the compartment which houses the motor and servo mechanism.



KINETIC SOUND SCULPTURE. TOTAL HEIGHT 7'.



THE BASE, AND LOWER PORTION OF WIRE AND PERSPEX COLUMN

Initial Conclusions to the Additional Developments

2.4.16. The kinetic-sound sculpture has now been working outside for prolonged periods. It has been observed that the rotation of the cylinder is directly proportional to changes in solar radiation. This enables the sculpture to exhibit an infinite variety of responses to daily and seasonal climatic cycles. These responses are usually subject to a time delay, which is the result of the piston adjusting to a change of temperature.

2.4.17. On a cloudless, or a continually overcast day movement is slight, but intermittent, often being triggered by occasional passages of cooler or warmer air over the piston. Under these conditions the column rotates a few degrees clockwise, then anti-clockwise. Sound is produced in single notes, and the accompanying distortions of the wire column may not differ greatly throughout the day. Sometimes sound may be emitted when there is no actual movement by the piston, this is caused by the forces of a string, overcoming the resistance of the plectrum with which it has been in contact.

2.4.18. On a day when the appearance of the sun is regulated by passages of cloud, movement is extensive and may even be almost continuous. Under these conditions the cylinder exhibits frequent and extremely varied patterns of distortion. The accompanying sound is produced in broad sweeps, which abruptly peter out into single occasional notes.

2.4.19. There is a very definite link between changes in the sun's radiation and the accompanying movement and sounds of the sculpture. This is made all the more pertinent, through the natural time delay of the piston. Perhaps this lack of simultaneity enables the observer to feel and assimilate, quite deeply, changes in the light and heat from the sun before they are, quite literally, orchestrated by the sculpture.

2.4.20. There is also a contradictory feature to this sculpture which was discussed in the opening section, (see paragraph 2.4.3.). In being constructed partly from piano wire and exhibited outdoors, the observer often associates the response of this sculpture to that of an Aeolian harp. In so doing it might be anticipated that sound is produced by wind reverbrating the wires. Yet since the sculpture is not wind driven it contradicts this principle. Instead it may produce sound when there is no wind, and no sound when there is wind.

General Conclusions to Developments involving the
integrated use of Chemical, Photoelectrical
and Mechanical devices

2.5.1. Because of the particular nature of this area, the research has produced a wide range of mechanisms with varying combinations of technological bases. Some of the mechanisms have made a specific contribution to the project through their extension into maquettes, and in one instance a full-size sculpture. However, many of the mechanisms exist as control devices and should be seen as making a general contribution to the development of kinetic sculpture which responds to the sun. Perhaps the latter may eventually be used as control mechanisms, or alternatively they may also form the technical and aesthetic basis for a range of maquettes and sculptures.

2.5.2. A part of the research in this area commenced by considering how the problems encountered in the chemical area, such as the loss of equilibrium and the fading of dyes, (see paragraph 1.1.23.) might be overcome with a combination of technical devices. To some extent this has been achieved by, -

- (a) The construction of a Chemical/Photoelectrical device of a size and type which enables the chemicals to be changed when, -
 - (1) There is a loss of equilibrium.
 - (2) The dyes have faded.
- (b) Subjecting the chemicals to frequent and abrupt changes in temperature, - Mechanical/Chemical area.
- (c) Frequently agitating the chemicals - Mechanical/Chemical area.

2.5.3. In the chemical/photoelectrical area a device was constructed in which the three-component chemical system became a daylight filter for a photocell, (see paragraph 2.1.1. - 8.). Thus the behaviour of the chemical system altered the resistance of the photocell. Used in this way the device becomes a control mechanism for translating combinations of changes in solar temperature and light into another medium, i.e. an electric motor or an artificial light source.

2.5.4. The first developments in the Mechanical/Chemical area were concerned with subjecting the chemicals to frequent and abrupt changes in temperature. This was accomplished by placing tubes containing the three-component chemical system, at the focal point of a parabolic reflector, (see paragraphs 2.2.8. -14.). In this way a range of colours became visible after inversion. Eventually a maquette was constructed, consisting of a tower of parabolic reflectors and a central column containing varying proportions of the chemical system. This tower was rotated by two heat sensitive pistons. Whilst this maquette enabled the chemicals to maintain a state of equilibrium, due to their being subjected to frequent and abrupt changes in temperature, no alternative was found to the Waxoline dyes. Due to the latter problem, no further work was attempted on this maquette.

2.5.5. To enable the pistons to rotate the Tower of parabolic reflectors a mechanical/electrical servo system was developed (see appendix section 7). It was realised that this servo-system had two distinct advantages over a purely mechanical servo system as used, for instance, in the mechanically operated sculpture in the previous chapter, (see paragraph 1.3.8.). These advantages are as follows,-

- (a) Very minor displacements of the piston can be amplified without the construction of a mechanical gearing system.

- (b) The piston need not be physically incorporated in the sculpture, but can drive it remotely.

2.5.6. Other developments in the mechanical/chemical area were concerned with agitating the three-component chemical system, (see paragraphs 2.2.1. - 7). In these developments tubes containing the chemicals were attached to piano wires, and the wires were plucked through the action of the heat sensitive piston. Whilst this enabled the chemicals to maintain a state of equilibrium it was realised that the system had,-

- (a) Aesthetic limitations; for practical reasons the tubes of chemicals and the wires could not be packed closely enough together to define the required spatial volume.
- (b) Technical limitations, still no alternative had been found to the fading Waxoline dyes.
- (c) The sounds and perturbations produced when the wires were plucked, had audio-visual possibilities.

2.5.7. In the mechanical/photoelectrical area the piston moved a sequence of coloured filters over an artificial light source, (see paragraphs 2.3.1. - 3.). This device exists as a possible control mechanism in which the temperature could cause the piston to operate an artificial light source in a kinetic sculpture. This could lead to an extension of the theme first developed in the chemical area (see paragraph 1.1.20) in which,

- (a) The colour of the sculpture becomes warmer as the temperature increases,-image by similarity.
- (b) The colour of the sculpture becomes colder as the temperature increases,- image by contrast.

2.5.8. In a later experiment the coloured filters were replaced by neutral density filters and a photocell was placed beneath them, (see paragraph 2.2.3.). Therefore, the response of the piston to temperature, together with fluctuations in illumination, changed the resistance of the photocell. This device remains a control mechanism, which could involve the response of a kinetic sculpture to combinations of changes in the light and heat from the sun.

2.5.9. Other developments in the mechanical/photoelectrical area involved the use of a steel or Perspex plate which was rotated through 90° by the piston. The aperture of a photocell was focussed on to one of the faces of this plate; consequently in moving the plate the piston caused the resistance of the photocell to change, (see paragraphs 2.3.4. - 6.). In this state the device was a control mechanism, but with specific aesthetic possibilities; which suggest a continuation of the sequence first noted in the mechanically operated slate and stainless steel sculpture in the first chapter, (see paragraph 1.3.16). These possibilities were connected with,-

- (a) Changes in sunlight being reflected in the surface quality of the mild steel.
- (b) Changes in sunlight often being accompanied by slight movements of the plate.

2.5.10. Developments followed in which Perspex rectangles were moved over the aperture of a photocell by the piston. (see paragraph 2.3.7. - 9.). This caused the resistance of the photocell to change according to the positions of the rectangles. Unfortunately, in being in contact and moving over one another, the surfaces of the Perspex became scratched. This reduced the illumination falling onto the photocell and the system became unreliable.

2.5.11. Due to the technical problems of abrasion this device had definite limitations. But aesthetically, it was realised that future work might entail the building of a sculpture consisting of

many of these rectangles. The rectangles could be programmed, so that particular configurations in the sculpture, reflected specific climatic states. In fact, this almost occurred when the rectangles were driven by the piston, since there was a square prism for minimum displacement, and a helix of rectangles for maximum displacement.

2.5.12. A further scheme took up this idea, and posed the concept of exhibiting a sculpture which responded to statistically predicted climatic conditions, alongside a sculpture which responded to the actual conditions for that period. (see paragraphs, 2.3.17 - 20.). The proximity of real to predicted conditions would be measured by making visual comparisons between the behaviour of the two sculptures.

2.5.13. This idea was eventually dismissed because of problems relating to the obscurity of the imagery. There seemed to be no really endemic quality about the configurations of these sculptures, which related them directly to cycles of solar light and heat. Instead, they struck up analogies between growth cycles in plants in response to actual (natural) and pre-programmed (synthetic) conditions. This took the imagery into an area which was only indirectly related to the project.

2.5.14. From the work in the chemical/mechanical area came the eventual construction of a kinetic-sound sculpture. This involved the use of the piston and servo system, together with further developments in the use of piano wires, springs and plectrums.

2.5.15. This sculpture has now been working over a period of eighteen months, during which time a number of factors have been observed. These suggest promising possibilities in connection with future work in the area of kinetic-sound sculpture. These observations, which are not set down in any order of priority, are as follows,-

- (a) The use of the electrical/mechanical servo-system does not require the piston to be physically incorporated in the sculpture, but instead, it can drive the sculpture remotely.
- (b) The response of the sculpture can be directly proportional to fluctuations in solar radiation.
- (c) Changes in solar radiation can be quite literally orchestrated, by sounds which emanate from the kinetic activity of the sculpture.
- (d) The natural time delay of the piston enables the observer to feel changes in temperature, before they are responded to by the sculpture. This can heighten the link between the sun and the performance of the sculpture.
- (e) In using materials, i.e. wires, in such a way that they may be initially associated with responses to air currents, (Aeolian harps, for instance) the response of this sculpture to solar radiation has opened up interesting contradictory possibilities.

Chapter 3

Final Area of Development

3.0.1. In the general conclusions to the first chapter the identification of a visual cause and effect sequence between changes in solar light and heat and the kinetic activity of the sculpture was discussed (see paragraph 1.4.10.). The identification of this cause and effect sequence suggests the emergence of a theme, in which patterns of movement can be developed which demonstrate the existence of states of wholeness between the sun (the cause) and the activity of the sculpture (the effect).

3.0.2. One of the developments in the chemical area resulted in the construction of a maquette, the responses of which related to patterns inherent in the annual temperature cycle (see paragraphs 1.1.16-22). Unfortunately, two major technical problems became apparent, these were a loss of equilibrium in the three-component chemical system, and the fading of the Waxoline dyes, (see paragraphs 1.1.23-24). To some extent these were overcome in the second chapter by the introduction of additional technical devices. For instance, the piston was used to vibrate the chemicals and also to rotate parabolic reflectors around them, in such a way that equilibrium was maintained (see paragraphs 2.2.2-7 and 2.2.8-15). But in both instances, equilibrium was maintained by relegating the chemical system to a part of a control mechanism, for translating changes in solar temperature into another medium. Problems connected with the fading of the dyes have not been overcome and therefore the chemicals need to be changed regularly. Clearly further developments concerning the direct aesthetic properties of this system must be suspended until a more suitable range of dyes becomes available.

3.0.3. No such technical problems were experienced in the mechanical area, where a stainless steel and slate coloured sculpture powered by wax filled pistons, was constructed. In this sculpture, stainless steel and slate planes, which are rotated by the pistons, open and close according to changes in temperature. This leads to two basic configurations; one which predominates for the hottest

summer months, and one for the coldest winter months. (see paragraphs 1.3.13. - 14.)

3.0.4. It has also been observed that the movements of the planes are usually proportional to changes in solar radiation. (see paragraphs 1.3.15 -16). In addition, the planes, in having each of their internal faces covered with mirror finish stainless steel, reflect a series of facets of the surrounding landscape. Therefore, variations in the quality of sunlight on the landscape, are simultaneously reflected in the sculpture. These fluctuations are then followed by the movement of the planes. As a result the observer witnesses a sequence of visual cause and effect relationships, (see paragraph 1.3.16) which can be interpreted as the visible reaction of a moving surface to the sun's heat. This sequence emerged again in chapter 2., where a piston rotated a mild steel or Perspex plate over a photocell, (see paragraph 2.5.9.).

3.0.5. However, this sculpture has been observed extensively since the conclusions were written up in the first chapter. These later observations suggest the performance of this sculpture is not always consistent with the cause and effect sequence. This jeopardises the existence of states of wholeness between the sculpture and the sun. The reasons for this apparent inconsistency in performance are as follows, -

- (a) Fluctuations in the visible light from the sun are not always synonymous with changes in temperature. Therefore movement does not always occur in the sculpture, despite the fact that an apparent visual cause has been recorded in the reflective surfaces of the planes. These circumstances are particularly applicable when light is reflected onto the sculpture.
- (b) The piston may respond to changes in temperature caused by:

(i) The passage of very local cooler or warmer air currents over the piston.

(ii) Fluctuations in the non visible wavelengths of light.

In each of the latter points, movement may take place in the sculpture when no apparent visual cause has been recorded in the reflective surfaces of the planes.

3.0.6. A technical problem also began to emerge. This is concerned with frequent adjustments which have to be made to take up the slack in the driving mechanism. If these adjustments are not carried out frequently then the sculpture loses much of its sensitivity and fails to respond to the more minor fluctuations in temperature. A complication then arises in which air currents move the planes and the sculpture becomes partially wind operated. This destroys the link between the sun and the kinetic activity of the sculpture.

3.0.7. If this cause and effect sequence is to be consistently carried through, future developments point towards the use of technical devices which only respond to the visible spectrum of sunlight. This suggests the use of photoelectrical devices. These will be used as a means of activating patterns of kinetic movement which consistently seek to explore the cause and effect sequence. It is hoped this will demonstrate the existence of states of wholeness, between the kinetic activity of the sculpture and sunlight.

3.0.8. Photoelectrical devices, as used so far in this project exist as control mechanisms and play an intermediary role between changes in sunlight, and the kinetic activity of the sculpture. They are further distinguished from the chemical and mechanical devices by their requirement of an electrical power source, which as far as this project is concerned, comes independently of the sun. This latter requirement can be viewed both as an advantage and disadvantage. The purist, unaccustomed to many of the technical and aesthetic

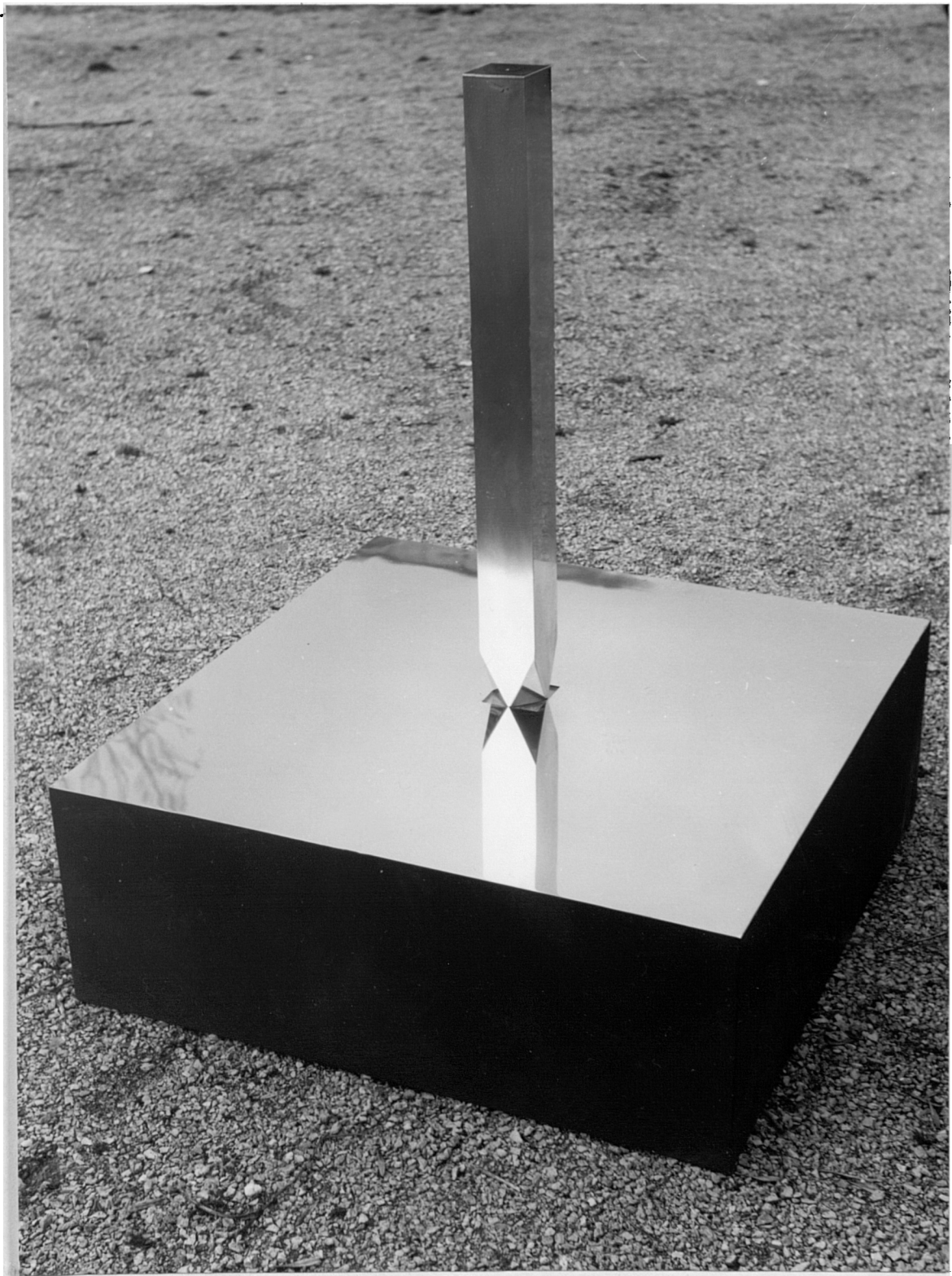
problems of kinetic sculpture might consider it a disadvantage. But an independent power source enables movement to exist as a constant feature, which responds to visible fluctuations in the quality of sunlight. It also enables the investigation of a wide range of kinetic activity, which extends from movement by change in position; to movement at speeds above our perceptual threshold. This range is described in more detail in paragraph 0.2.42.

3.1.1. The first practical result of the preceding observations and suggestions, was the construction of the maquette, which is shown in the photograph on page 106. This maquette attempts to translate fluctuations in sunlight (the cause), into one of a series of six, appropriate colour changes (the effect).

3.1.2. The particular compositional elements of this maquette were chosen because they are analogous to the first known sundials (see Introduction, paragraph 0.1.10.). This was done in an effort to emphasise an archetypal association, between the maquette and the sun. For this reason the vertical element is an obelisk, which is analogous to a gnomon. This is mounted at the centre of a square, the latter is analogous to the dial plate of a sundial.

3.1.3. The actual construction of this maquette is described in more detail in section 8 of the appendix; briefly, it is as follows. The base of the maquette is 2' 5" square, and is made of mirror finish stainless steel. This reflects the behaviour of the sky and enables the resulting fluctuations in sunlight to be observed. As a contrast to the mirror finish base, the obelisk is constructed almost entirely from sheets of satin finish stainless steel. Only the four triangles at the foot of the obelisk are polished.

3.1.4. Immediately below these triangles are four apertures of clear Perspex. Through the introduction of an artificial light source in the base, colours are projected through these apertures



MAQUETTE, BASE 2' 5" x 2' 5".

onto the triangles above. The particular colour is selected from a spectral progression of six colours which range from red to dark blue. This selection is achieved by adapting the sample and hold circuit used in the previous photoelectrical area, (see appendix section 3). Each of these six colours represents a particular difference in illumination levels, between the past and current thirty seconds of sunlight. The hotter the colour, the greater is the difference between penultimate and present. In this way the actual behaviour of the sky, which is reflected in the stainless steel base of the maquette, is juxtaposed with a corresponding colour change in the four small triangles at the foot of the obelisk.

3.1.5. Many technical problems were experienced during the construction of this maquette. Undoubtedly the most difficult problem was that of introducing a powerful enough light source into the base, that would enable coloured light to be projected at an intensity which clearly illuminates the foot of the obelisk. However, this was eventually overcome, and the response of the maquette to fluctuations in sunlight has been observed.

3.1.6. As the reflection of the sky is seen to change in the stainless steel base of the maquette, so the colour at the foot of the obelisk changes, and eventually adjusts. In this way fluctuations in sunlight, (the cause) can be identified with a change in the colour of the artificial light source, (the effect). However, the link between particular colours and specific fluctuations in illumination is often ambiguous. For instance, the appearance of red light at the foot of the obelisk, does not seem to clarify any strong visual link relating to the wide divergence between measurements of the immediate past, and current thirty seconds of sunlight. Instead, colour as used in this maquette can tend to obscure the issue. In moving from cool to warm, the maquette not only attempts to suggest fluctuations in illumination, but it also implies fluctuations in temperature. This is incorrect and can be misleading, as light intensity rather than temperature is being measured.

3.1.7. Perhaps in this maquette I was subconsciously influenced by the maquette constructed in the chemical area (see paragraphs 1.1.1. - 22.). In this, colours do change in response to temperature. Certainly the obelisk, rather like a pole with colours appearing on part of it, is not unlike the chemical maquette where colours appear and disappear inside poles. It seems that I was attempting to transpose the response of a temperature sensitive system into that of a light sensitive system. In this instance the mode of transposition was, to some extent, inappropriate.

3.2.1. Despite the limitations of the previous maquette, the compositional elements which had been used were strongly evocative of the imagery associated with sundials. (see paragraph 3.1.2.) This suggested a link between the maquette and the sun, even before any kinetic activity took place. As a consequence, I began to consider the alternative possibility of transposing fluctuations in sunlight into actual movement, instead of a series of corresponding colour relationships. If this movement was to be achieved within the compositional constraints of the sundial, then it appeared there were two basic alternatives,-

- (a) The gnomon (the vertical element) had to move.
- (b) The dial plate (the horizontal element) had to move.

3.2.2. Developments followed, which investigated how these fluctuations in sunlight might be transposed into actual kinetic movement. These developments centred upon the concept that one observes in the sky, (and by the sun's effect on the environment) a continuous release of the sun's energy. This energy is regulated by the annual cycle of the sun, and such climatic factors as the relative absence or presence of cloud cover are also involved. The regulation of the sun's energy by its annual cycle, is directly proportional to the sun's position, relative to the earth. Alternatively, what I became more interested in investigating was

the way the sun's energy is regulated by the appearance of cloud cover. For instance, if the sun is intermittently obscured by the passage of broken cloud, there is a corresponding rise and fall in the proportion of solar energy which reaches a particular area of the earth. This rise and fall in energy consists of a series of illumination peaks and troughs. With total cloud cover the observed solar flux varies less, and produces shallower peaks and troughs.

3.2.3. I realised that photoelectrically, this rise and fall in the sun's energy could be converted into a proportional rise or fall in voltage; this could control the speed of an electric motor. In this way patterns of kinetic movement could be developed which continually attempted to match and adapt to fluctuations in the sun's energy. In an attempt to realise this possibility the sample and hold circuits were again used, (see appendix section 3).

3.2.4. It was envisaged, that with the use of these circuits, a potential sculpture or maquette could be developed, which would continually attempt to maintain a steady state, during which there would be no kinetic activity. This steady state would be achieved by a continual process, in which the sampling circuit monitored the illumination for thirty seconds, this information would then be logged and compared to the next thirty seconds of illumination. If there was no change in illumination, kinetic activity would not take place. Alternatively, a fluctuation in illumination which was different to the previous thirty seconds of illumination, would be accompanied by a proportional response in the kinetic activity of the sculpture. The latter would continue, until the penultimate and present thirty seconds of illumination became identical.

3.2.5. Experiments followed in which a mirror finish stainless steel sheet, with an opening in the centre, was placed over a central column. This sheet was rocked with a simple cam mechanism. Power was applied through a six volt Monoperm motor and the speed was controlled by amplifying the output from the sample and hold circuits. This caused the rocking motions to bear a direct relationship to the

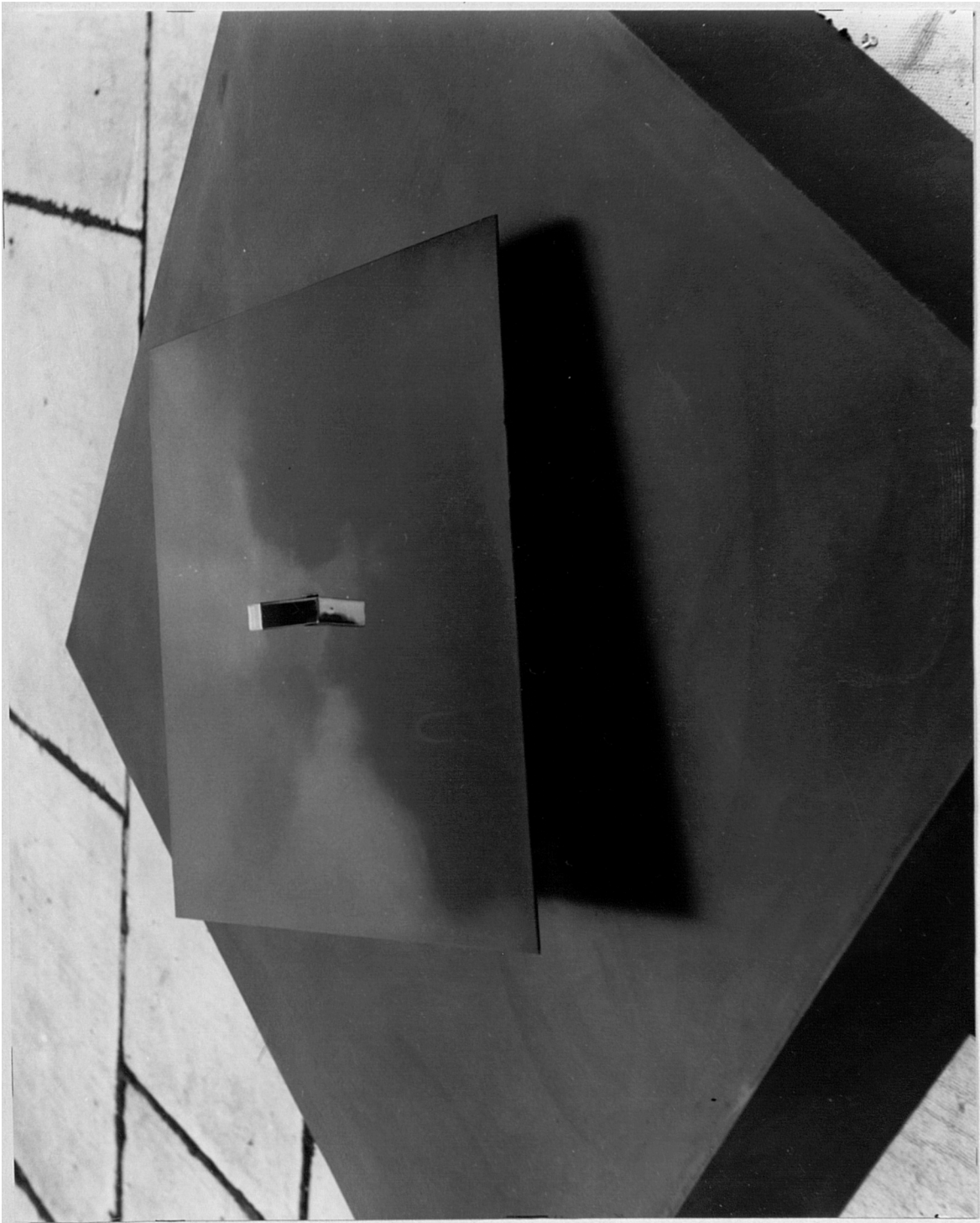
fluctuations in sunlight.

3.2.6. In these experiments certain limitations were observed. The stainless steel plate was rocked by a single cam from one position only, and the degree of movement was therefore unevenly distributed. In addition, the little six volt motor had difficulty in rocking the plate at slow speeds, despite an elaborate gearing mechanism. Obviously the weight of the plate had to be reduced. There was also some uncertainty about the suitability of the surface quality of the mirror finish stainless steel. In observing the movements, the eye did not settle on the plate, but was continually repulsed.

3.2.7. Many of the problems which have been highlighted, were overcome in the maquette, which is shown on page 111. The base of this maquette is four feet square, and is covered with matt black Formica. In the middle of this base is a chromium plated gnomon, this has an aperture at its top; below this aperture is a photocell. Immediately around the gnomon is a black Perspex plate, (the dial plate) which is rocked by four cams beneath. The motor and the accompanying sample and hold circuits are all housed in the base.

3.2.8. The problem of the uneven distribution of movement was overcome by using nylon cams, positioned in such a way that they rocked the plate at alternate intervals. (This along with further details of the construction, is shown in section no. 9 of the appendix). This led to a pattern of movement which implied a rotational motion; the latter contrasted well with the orthogonal form of the maquette.

3.2.9. The problems connected with the use of stainless steel, its weight and surface quality, were resolved by the use of a $\frac{1}{8}$ " thick Perspex sheet which was reinforced on its underside. This reduced the load on the electric motor and enabled the plate to be rocked, even with an input of one volt. The Perspex also alleviated the problems connected with the surface quality of the stainless steel. Black Perspex, with a highly reflective surface was eventually



MAQUETTE, BASE 4' x 4'.

chosen. This mirrored the motions of the sky in a way that enabled the eye to settle on the plate, and continually observe its movements.

3.2.10. As soon as this maquette became fully operational, it was observed frequently during a wide range of different climatic variations. These observations suggest that as far as this project is concerned, the translation of fluctuations in sunlight into actual kinetic movement, (as opposed to their translation into a series of corresponding colour relationships) is far more appropriate. Cloud movements, and the resulting fluctuations in sunlight, are clearly visible in the Perspex plate. This enables the cause to be continually juxtaposed with its effect, i.e. the movement of the plate.

3.2.11. The range of responses of this maquette to particular climatic states, are as follows.-

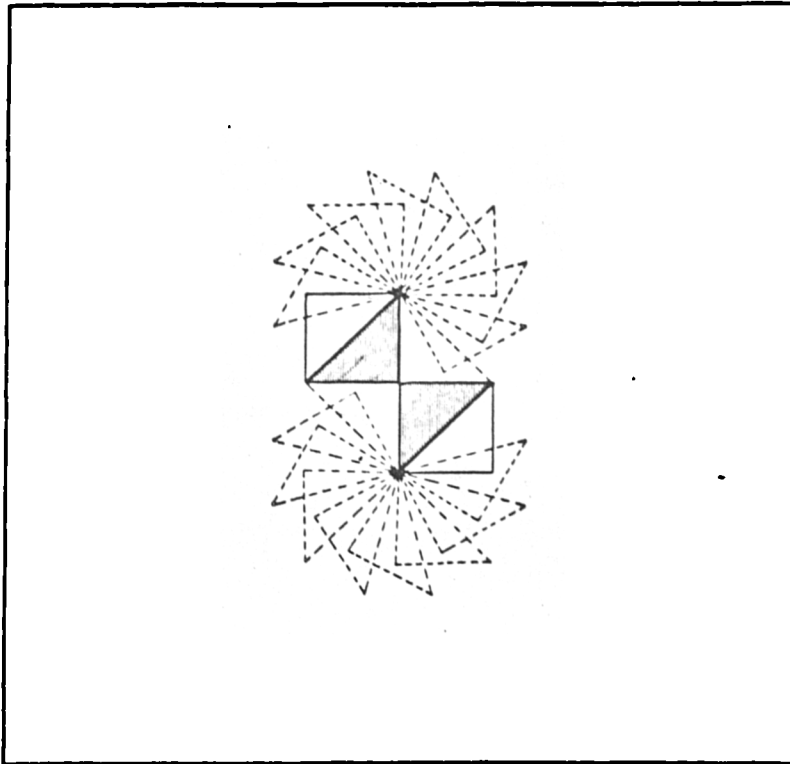
- (a) Intermittent cloud cover. Kinetic activity is at its most passive when dense clouds obscure the sun, but as soon as the cloud cover breaks the sun is visible, and kinetic activity is at its most vigorous. This lasts until the maquette has adapted to this increase in illumination, whereupon the kinetic activity becomes passive. As soon as the sun has become obscured by cloud again, kinetic activity is resumed and eventually ceases when the maquette has adapted to this reduction in illumination.
- (b) Almost total cloud cover where there are only very minor and infrequent fluctuations in illumination. Kinetic activity occurs intermittently and is usually slow and ponderous.
- (c) Bright clear sky. Movement seems to occur at regular intervals of the sun's daily cycle.

3.3.1. I next attempted to construct a maquette which would respond to the annual cycle of the sun, and also to momentary fluctuations in sunlight. I intended to resolve the first point by programming the sculpture to exhibit two basic configurations, one to approximate with midwinter, and one with midsummer. I realised the beam splitting properties of transparent glass or Perspex, could be used to emphasise the very minor movements in the maquette, such as those brought about by momentary fluctuations in sunlight. For the latter reason, prisms were considered.

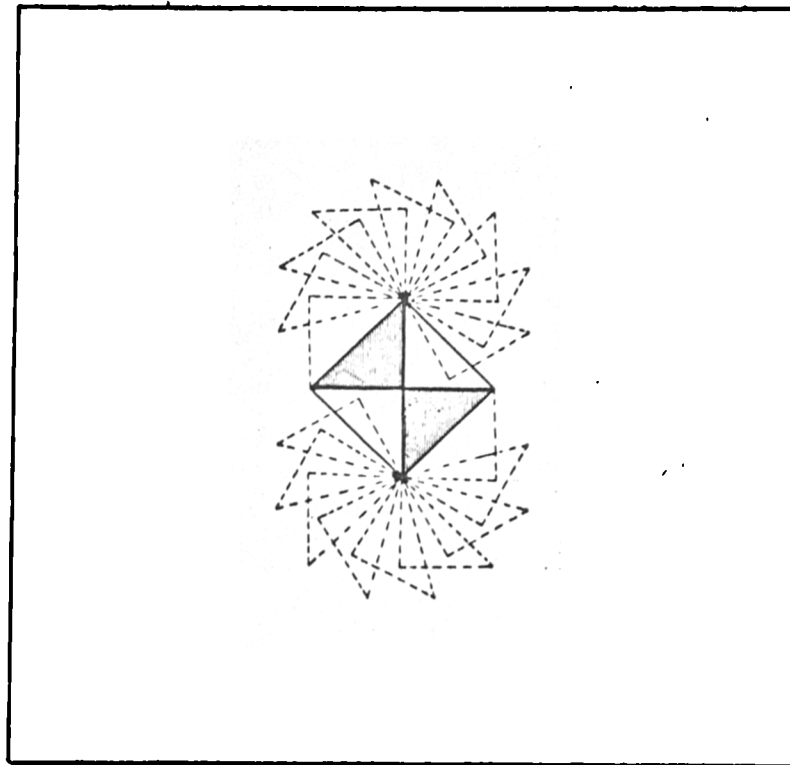
3.3.2. Experiments commenced with combinations of triangular and square prisms to determine how, by rotation, a system could be evolved in which there were two basic configurations. Six maquettes were constructed to explore these possibilities. Four identical triangular prisms, six inches in height, were eventually selected. Two of these prisms are fixed, and two rotate through 270° . This gives rise to the sequence shown in plan on page 114, involving one square prism, and two narrower rectangular prisms.

3.3.3. From the two configurations, the single large square prism was chosen to represent midwinter, and the two smaller rectangular prisms for midsummer. In this way, the movement of the prisms images the response of nature to the sun's annual cycle; there is a gradual closing up of the forms towards midwinter, and a gradual opening out towards midsummer.

3.3.4. In the finished maquette shown in the photograph on page 115, the moving prisms are made in Perspex. This enables their beam splitting properties to emphasise the almost imperceptible movements, caused by slight and momentary fluctuations in sunlight. These prisms are cemented to chromium plated bases. At the inside corner, on the underside of the bases, are welded $3/16$ " diameter rods. These project down into the base, and enable the prisms to be rotated.

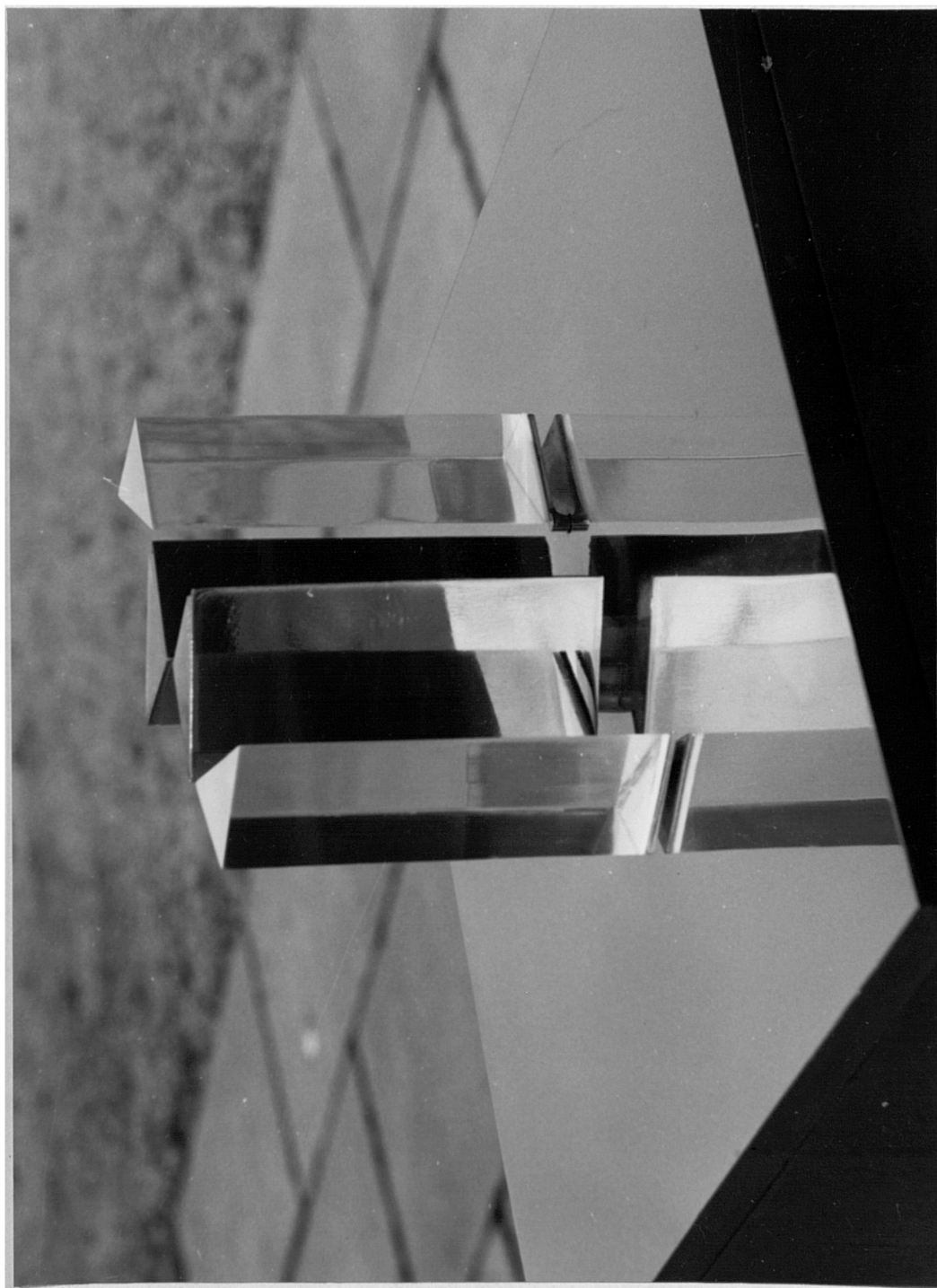


SUMMER



WINTER

PLAN SHOWING MOVEMENTS OF THE PERSPEX PRISMS BETWEEN THE SUMMER AND WINTER SOLSTICES.



MAQUETTE. BASE 12" x 12".

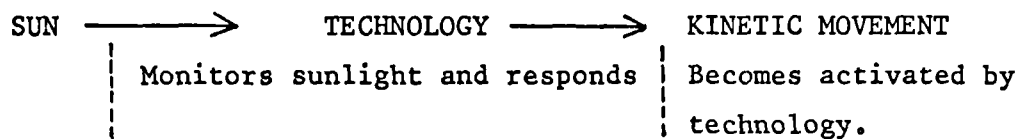
3.3.5. As a contrast to the transparent qualities of the moving prisms, the fixed prisms are made from chromium plated mild steel. The tops to each of fixed prisms are covered with semi-opaque Perspex, beneath which is positioned a photocell.

3.3.6. The base of this maquette is one foot square, and is covered with mirror finish stainless steel. This was chosen because of its proven ability to mirror the sky, and also to show up the spectral patterns. The size of the base was decided by the area required to show up the beam splitting activities of the prisms.

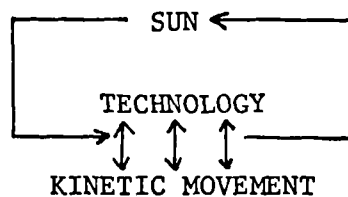
3.3.7. Each Perspex prism is rotated through its 270° by a Sanwa I.C. mini servo motor. These motors are housed in the base immediately below the prisms, and are connected to the photocells above. With the use of an artificial light source, the servo motors are tuned to respond to a range of illumination thresholds, commencing from the winter solstice and extending to around the summer solstice, see appendix section 2. A more detailed description of the photoelectrical response mechanism is also given in the appendix, see section 10.

3.3.8. This maquette has been placed outside on a variety of days and its performance has been observed. During the month of June (the month of the summer solstice) and into July, the prisms rotated sufficiently to form the two smaller rectangles. It is also known that the prisms will close to form one large square prism at and around the winter solstice. The latter behaviour also occurs at every sunset and is followed, except in midwinter, by the prisms commencing their rotation at sunrise. The response of the maquette to minor fluctuations in daylight is marginal, and is observed more through the spectral patterns flickering about the maquette, than through the actual movement of the prisms.

3.4.1. In the work which has been discussed in this chapter, forms which are historically common to solar phenomena, were deliberately selected in an attempt to heighten associations between the sun and the maquettes. This has been discussed in detail in relation to the first two maquettes in paragraph 3.1.2. and 3.2.1. In the later maquette, this association was attempted through the use of rotating prisms. Whilst in each of the maquettes, the use of these forms and their movements has heightened associations with the sun, there is the limitation that movement is merely applied by the introduction of a technical device. This reveals a dichotomy between the application, and the movement. The result is a one way system which proceeds as follows,-



3.4.2. In order to reduce this dichotomy between the application and the movement, the two had to become technically and aesthetically interactive. It was realised that interaction would be achieved by building either positive or negative feedback into the system. This would enable the technology to become a part of the kinetic movement, and conversely the kinetic movement to become a part of the technology. This interactive system can be expressed as follows,-



3.4.3. The decision to develop an interactive system emerged by once again investigating the possibilities of changing the resistance of photocells by exposing them to moving reflective surfaces. This was first explored in Chapter 2, see paragraphs 2.3.4. - 6, and the diagram on page 77.

3.4.4. To assist these investigations an artificial sky was constructed (see appendix, section 11). Through the use of statistical information, (see appendix, section 2) this artificial sky enabled the annual cycle of the sun, and daily fluctuations in sunlight, to be simulated. This simulation was achieved by adjusting the position and intensity of an artificial light source, (the sun). By placing photoelectrical devices inside this artificial sky, it was possible to approximate their response to any particular time of the day or year.

3.4.5. Experiments subsequently commenced in which a square metal plate with a reflective surface was rotated by either a Monoperm motor, or a Sanwa mini servo motor. A photocell which formed part of the control circuits for each of the motors, was focussed onto the reflective surface of the plate. The resistance of both of the circuits was tuned by,

- (a) Restricting the aperture over the light sensitive face of the photocell.
- (b) Adjusting the potentiometers.

This enabled the plates to rotate until their surfaces reflected a specific amount of light onto the photocells. When this occurred, a voltage relay in the circuit controlling the Monoperm motor was operated, which caused the motor to stop. ⁽³⁸⁾ Motion caused by the Sanwa motor ceased, when the system became stable, (see appendix section 10).

3.4.6. From these investigations the following points emerged. The voltage relay could be triggered, and cause the Monoperm motor to rotate a reflective plate at a constant speed in one direction, by either,-

- (a) A rise in illumination above a pre-selected threshold.
- (b) A fall in illumination below a pre-selected threshold.

Therefore, the motor can only run intermittently when the level of illumination fluctuates about this pre-selected threshold.

3.4.7. The system powered by the Sanwa motor responded to an extensive range of illumination. (A fact already discovered in the previous maquette, see paragraph 3.3.7.). By using the artificial sky this range was shown to extend from a dull overcast midwinter day, to a bright summer day. The system was also observed outside, and it was found that the plate rotated through varying degrees and speeds of clockwise and anti-clockwise movement; this appeared proportional to the fluctuations in sunlight. But this movement was restricted to 270° , and could not be increased because of the limited output of the motor.

3.4.8. It was decided to take the 270° of movement of the Sanwa powered system as a natural limitation. In much the same way the constant speed of the motor in the Monoperm powered system was considered a limitation. But in the latter there were possibilities which could enable the pre-selected illumination threshold to float. This involved the movement of the reflective plate through several revolutions in response to extensive changes in illumination.

3.4.9. To obtain a floating threshold level it was decided to let the Monoperm motor rotate the spindle of the potentiometer in the circuit. This would vary the resistance of the circuit. But since the potentiometer had only the normal 270° of traverse, the motor could not drive the potentiometer continually in one direction. Therefore the direction of the motor had to change when the potentiometer reached the end of its traverse. This was achieved by constructing a circuit to switch the polarity of the motor. (see appendix section 12)

3.4.10. Unfortunately, despite these modifications, movement was not as extensive as had been anticipated. It was therefore decided to introduce positive feedback into the system and the following

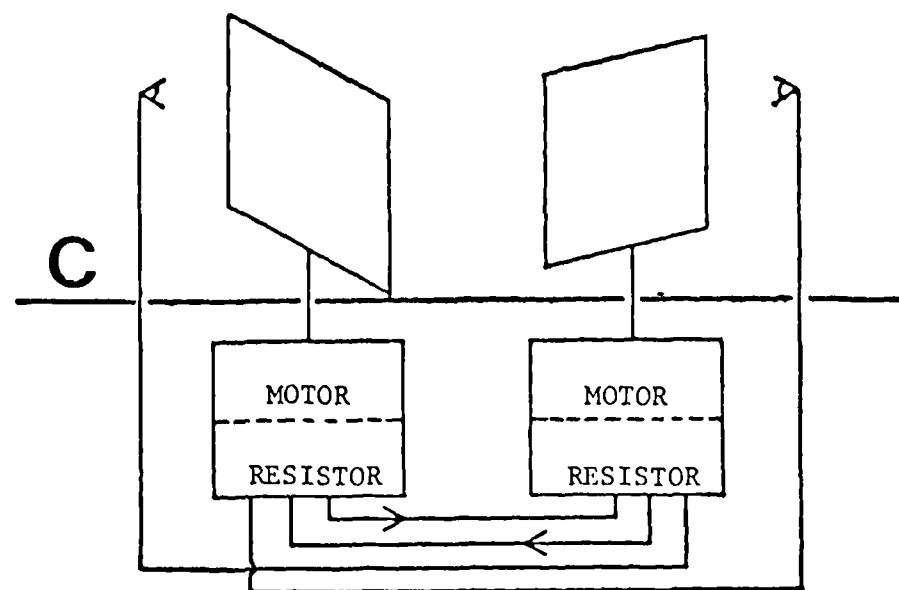
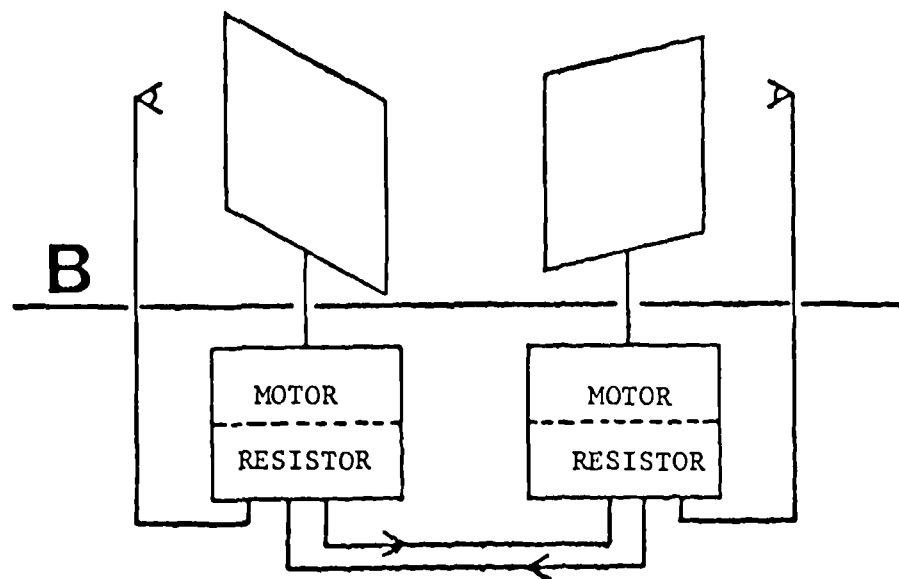
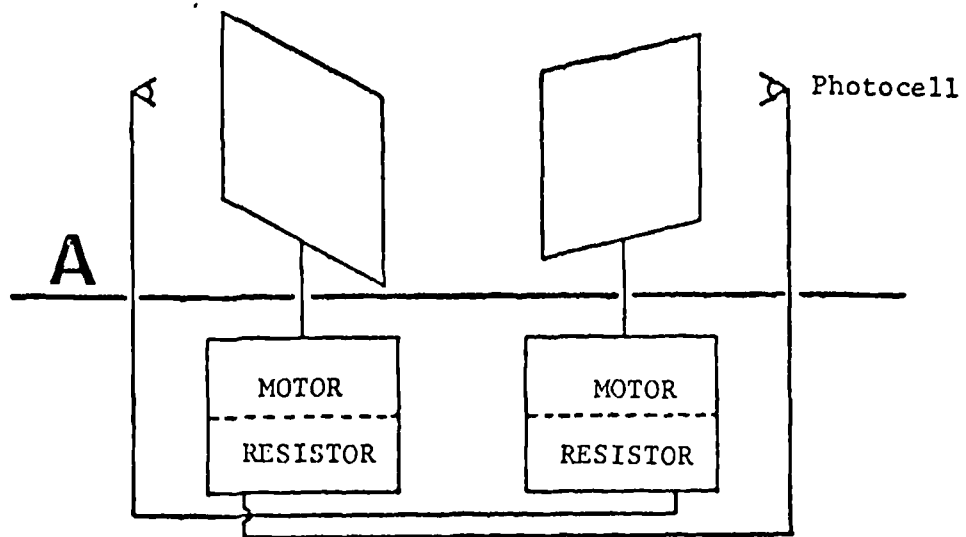
three alternatives were investigated, these are also described diagrammatically on page 121.

- (a) Crossing the photocells over in two identical systems.
- (b) Crossing the potentiometers over in two identical systems.
- (c) Crossing both the potentiometers and photocells over in two identical systems.

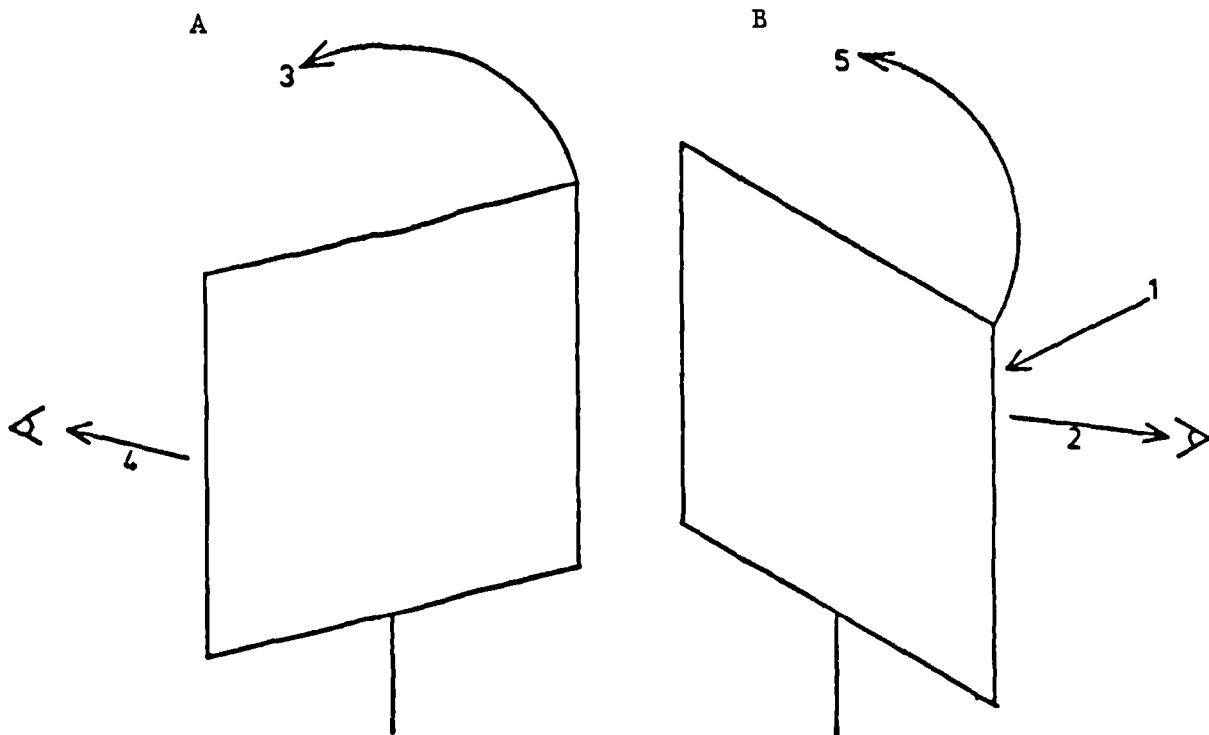
The results were observed, and these suggested that the crossing over of the photocells produced a range of movements which clearly demonstrate the cause and effect sequence. This range is described on page 122.

3.5.1. A working maquette was finally constructed using the positive feedback system; this is shown in the photographs pages 123-124. The maquette consists of a mirror finish stainless steel base, upon which are fixed two 6" high triangular mild steel prisms. These are positioned on an east-west axis (as shown in the drawing on page 125) in such a way that the space between them is defined as a narrow spatial volume. This narrow spatial volume is punctuated by the intermittent movements of two 6" square, bright mild steel planes which revolve in between the prisms. The area covered by this rotation is shown by the surrounding thin line in the drawing.

3.5.2. The exterior surface quality of the prisms was obtained by applying 320 grade wet and dry paper. Both the interior and exterior surfaces of the prisms were then treated with clear polyurethane lacquer. A $\frac{1}{8}$ " diameter aperture was drilled in the centre of the inside faces of the prisms, and sealed with clear Perspex. The prisms are placed in such a way that the two apertures

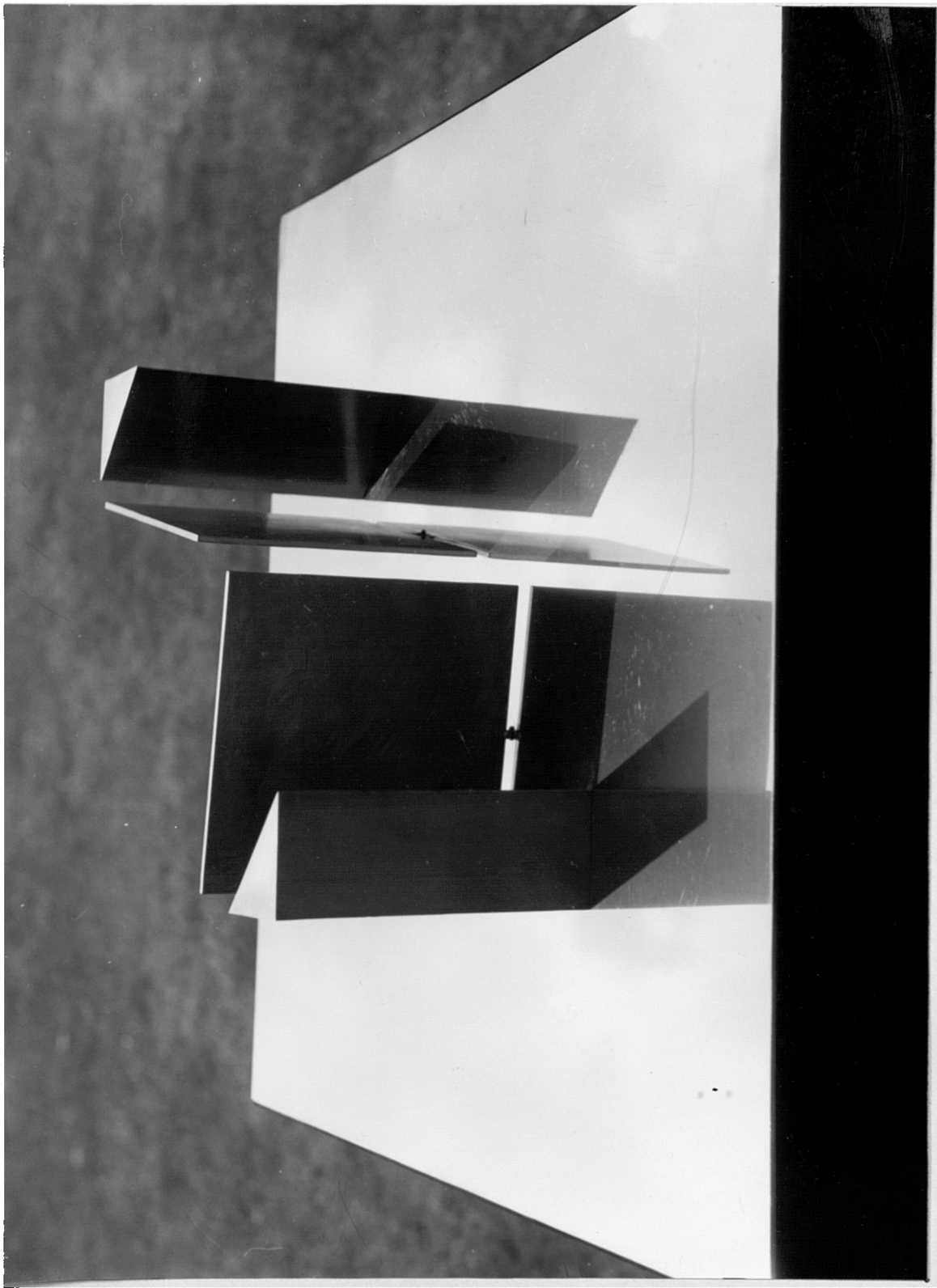


THE THREE FEEDBACK SYSTEMS

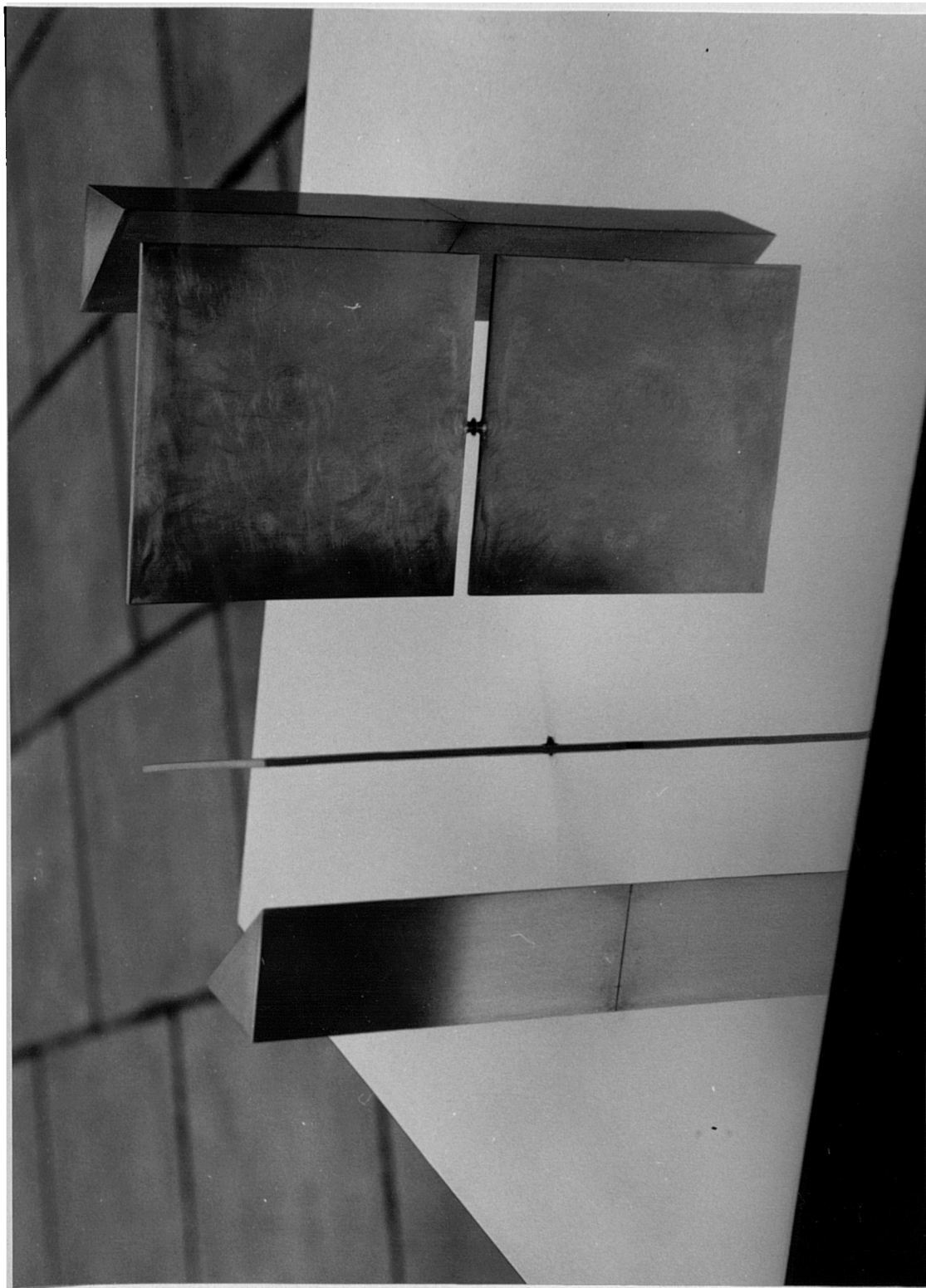


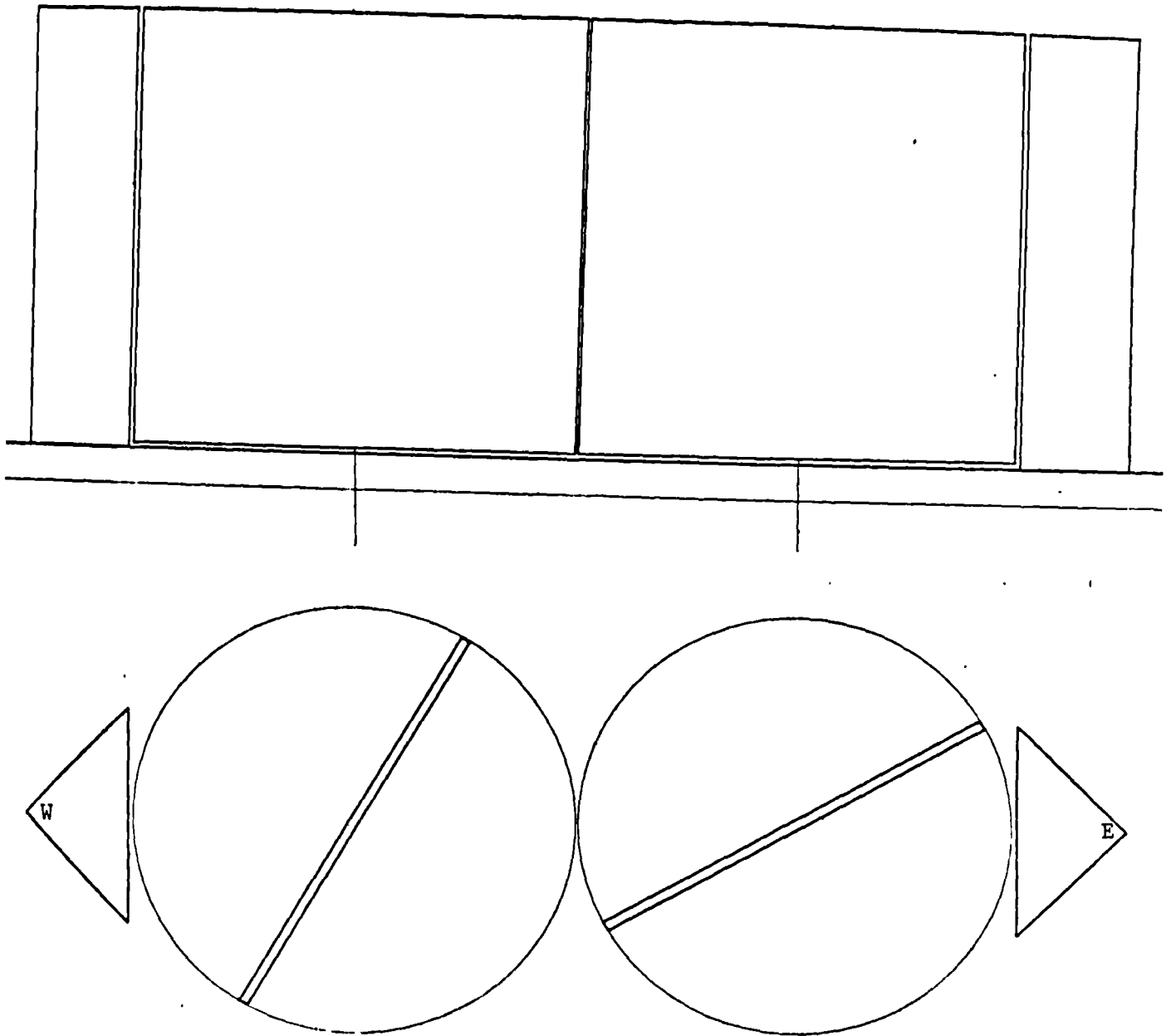
A typical response of the system is as follows. The day is predominantly overcast, suddenly the sun breaks through and triggers the following series of cause and effect movements, which continue until the system stabilizes.

- 1. The sun shines on to plate 'B'
2. Sunlight is reflected onto the photocell and the resistance of the circuit changes.
3. Plate 'A' rotates. (This is movement by contrast, since initially one might expect plate 'B' to rotate.)
4. The rotating, plate 'A' changes the amount of light reaching its adjacent photocell.
5. Plate 'B' responds by rotating.



MAQUETTE, BASE 1' 10" x 1' 10".





ELEVATION AND PLAN OF TWO PRISMS AND TWO REVOLVING PLANES.

are directly opposite and are focussed onto the axis of the rotating planes. An ORP 12 photocell is placed inside each of the prisms, with its light sensitive face $\frac{1}{4}$ " away from the aperture. Wires from the photocells run into the base of the maquette, the photocell on the right being wired into the circuit controlling the motor on the left, and the photocell on the left being wired into that on the right. This combination was chosen for the reasons suggested in paragraph 3.4.10.

3.5.3. The bright mild steel planes have honed surfaces, which enables the photocells to respond to an extensive scattering of light. In common with the prisms, the surfaces of the planes are protected with clear polyurethane lacquer. On the underside edges of each of the planes is brazed a 3/16" diameter spindle. These spindles rotate in Nylon bearings in the base, and are connected to two six volt Monoperm motors. The latter are used in conjunction with the relay circuits, ⁽³⁸⁾ and the polarity switching circuits, (see appendix section 12).

3.5.4. Investigations followed, in which the maquette was subjected to a wide variety of real and simulated climatic conditions. In these investigations the maquette was positioned on an east-west line, as shown in the drawing on page 125. This positioning enabled each of the photocells to be exposed to equal durations of the sun's cycle. Positioning on an east-west line, also leads to the major axis of the maquette defining the demarcation between the spring and autumn equinoxes. Therefore, the sun is only reflected off the north faces of the maquette during the early mornings and the evenings between the spring and autumn equinoxes. This could not occur if the maquette was placed on a north-south line; as the aperture in the face of the prism at the southern end of the maquette, would be in shadow for most of the year. Therefore the photocells would receive unequal amounts of light; simulated tests have shown this might lead to the rotational movements of the southernmost plate predominating for most of the year.

3.5.5. The maquette had now been fully operational for extensive periods. When placed out of doors, a situation gradually develops where kinetic movement commences at sunrise, continues intermittently through the day, and finally terminates around sunset. Frequent observations of this daily cycle of kinetic movement have highlighted the following points,-

- (a) The reflective stainless steel base has again served as a suitable means through which the movements of the sky, and the resulting fluctuations in sunlight, can be observed as the cause of kinetic movement in the maquette. In having a mirror finish, this base has also increased the reflective properties of the maquette, and kinetic movement has become more responsive to minor fluctuations in sunlight.
- (b) Although the planes rotate at a constant speed, their degree of rotation appears directly proportional to the fluctuations of sunlight observed in the base. For instance, with intermittent cloud cover movement is extensive but irregular, and can often extend to several revolutions. With total cloud cover movement is occasional, and may often be no more than a few degrees of rotation. In a cloudless sky movement is predictable and extensive, and can be seen to relate directly to the sun's position.
- (c) When the sun is due east of the maquette, the main rotational movements usually occur in the plane on the west side. These movements are frequently contrasted with the secondary rotations of the plane on the east side. Therefore for most of the year, the movement of the plane on the western side is predominant in the morning, whilst the movement of the plane on the east is predominant in the afternoon.

3.5.6. These observations suggest that the response of this maquette to sunlight, has opened up a specific line of investigation which is of central importance to further work in this project. This is because the cause and effect sequence described in paragraph 3.4.2. , has been realised to the extent that states of wholeness do seem to exist between the kinetic movement of the maquette and changes in sunlight. As a result, the relationship of the technical devices in this maquette, has become technically and aesthetically interactive with the forms and their patterns of movement.

3.5.7. For example, as one of the planes rotates due to a fluctuation in sunlight, it undergoes both a qualitative and quantitative change. This qualitative change is connected with the way in which the plane's actual form, and the perceptual nature of its surfaces and edges, are transformed by rotation and changing light and shadow patterns. But this rotation also causes the adjacent photocell to undergo quantitative changes; the latter may cause or prevent additional movements occurring in the other plane.

3.6.1. As a result of the points which emerged from the last maquette, I decided to construct two more maquettes. These would explore the possibilities of a wider range of kinetic movement which extended beyond the aesthetic confinements of a narrow spatial volume, (as had been the case in the previous maquette, see paragraph 3.5.1.). These maquettes were constructed almost simultaneously, in order to compare the results of kinetic movement which occurs within the following two contrasting situations,-

- (a) Movement which occurs within a defined rectangular spatial volume, where the axis lines of the volume converge on a common centre.

- (b) Space which is displaced in the direction of kinetic movement, by the axis lines radiating from a common centre.

Both 'a' and 'b' are described in more detail in the diagram on page 131.

3.6.2. In both maquettes it was also decided to emphasise differing time and space relationships, through the response of a wider range of kinetic activity. This involves, -

- (a) Movement at different speeds
- (b) Movement at different intervals

3.6.3. The maquettes which were subsequently constructed are shown in the photographs on pages 132 and 134. The maquette shown in the photograph on page 132, and in the drawing on page 133, consists of four 6" high triangular prisms, placed at the corners of a 1' 2" square. This results in the definition of a rectangular spatial volume, as described in point 'a' of the previous paragraph. At identical points on the mirror finish stainless steel base, are pivoted four 6" square rotating mild steel planes. The position of the latter emphasises the two main axes of the maquette. The material and surface treatment of both the plates and the prisms, is identical to that used in the previous maquette, (see paragraph 3.5.2.).

3.6.4. In the centre of the inside face of each of the prisms is a 11/64" diameter aperture, which is sealed with Perspex. The apertures are lined up across the four cardinal points of the compass, (see drawing, page 133). Therefore the aperture in the inside face of the west prism is focussed east, and the aperture in the face of the east prism is focussed west. The same situation prevails for north and south. At a distance of 1/4" behind each of the apertures, is placed the light sensitive face of an ORP12

photocell. Wires from these photocells run into the base and from a part of the circuits which control one of the Sanwa motors.

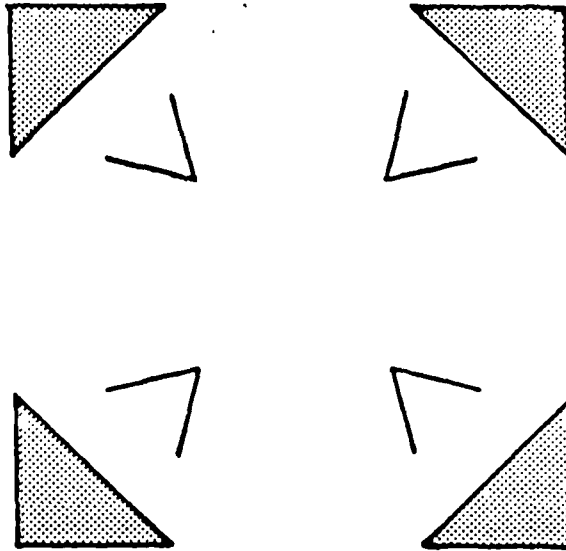
3.6.5. As in the previous maquette, (see paragraph 3.5.2.) positive feedback was again introduced as a means of achieving more extensive passages of movement. This was accomplished by crossing over the photocells in the following order,-

1. Photocell in North prism, controlling South plane.
2. Photocell in South prism, controlling North plane.
3. Photocell in West prism, controlling East plane.
4. Photocell in East prism, controlling West plane.

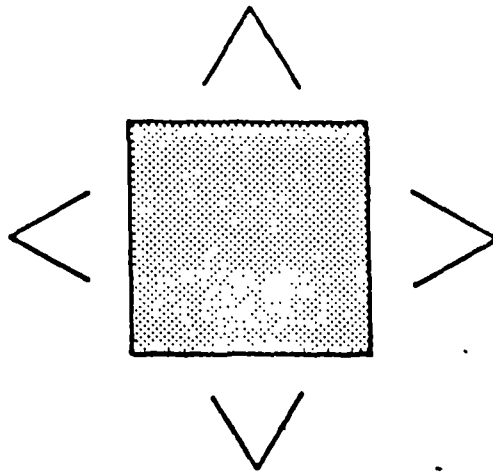
3.6.6. In the maquette shown in the photograph on page 134, and the drawing on page 135, a 5" high by 2" square rectangular prism is fixed in the centre of a mirror finish stainless steel base, in such a way that its vertical faces line up with the four cardinal points of the compass. The prism displaces space in the direction of four 5" square rotating planes; this meets with the requirement outlined in point 'b' paragraph 3.6.1. The area of movement of these planes, is shown in the drawing by the four incomplete circles. The surface treatment of both the prism, and the four rotating planes, is again identical to that used in the previous maquette, see paragraph 3.5.2.

3.6.7. At the centre of each of the four vertical faces of the prism is a $\frac{1}{8}$ " diameter aperture, which is sealed with clear Perspex. Inside the prism, at a distance of $\frac{1}{4}$ " away from each of the apertures, is positioned the light sensitive face of an ORP12 photocell. The wires from each of the photocells run into the base of the maquette. As in the other maquette, (see paragraph 3.6.5.) positive feedback was again introduced by crossing the photocells over. For instance, the photocell behind the aperture in the north face of the prism, is wired into the motor which controls the movements of the south facing plane.

A

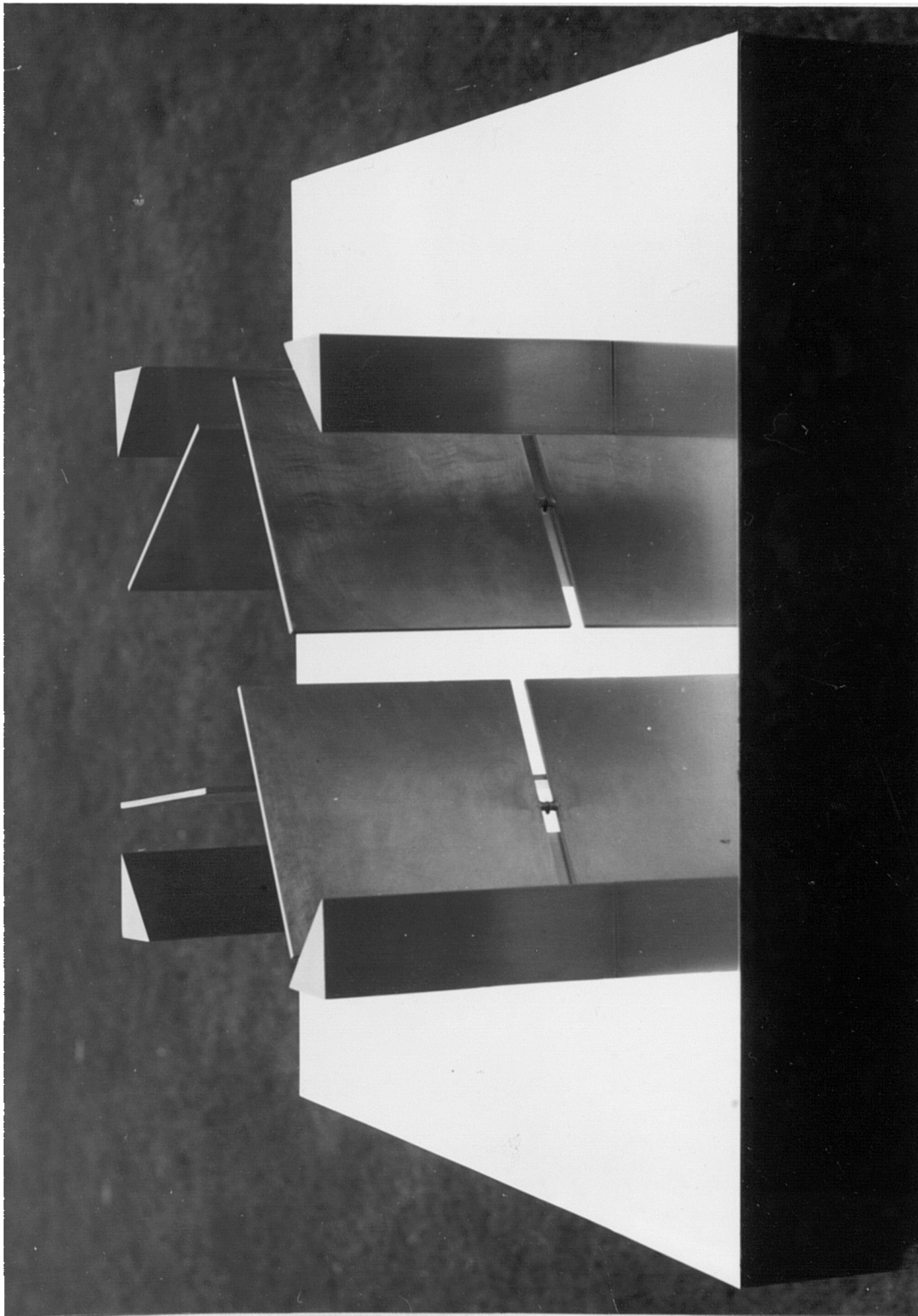


B

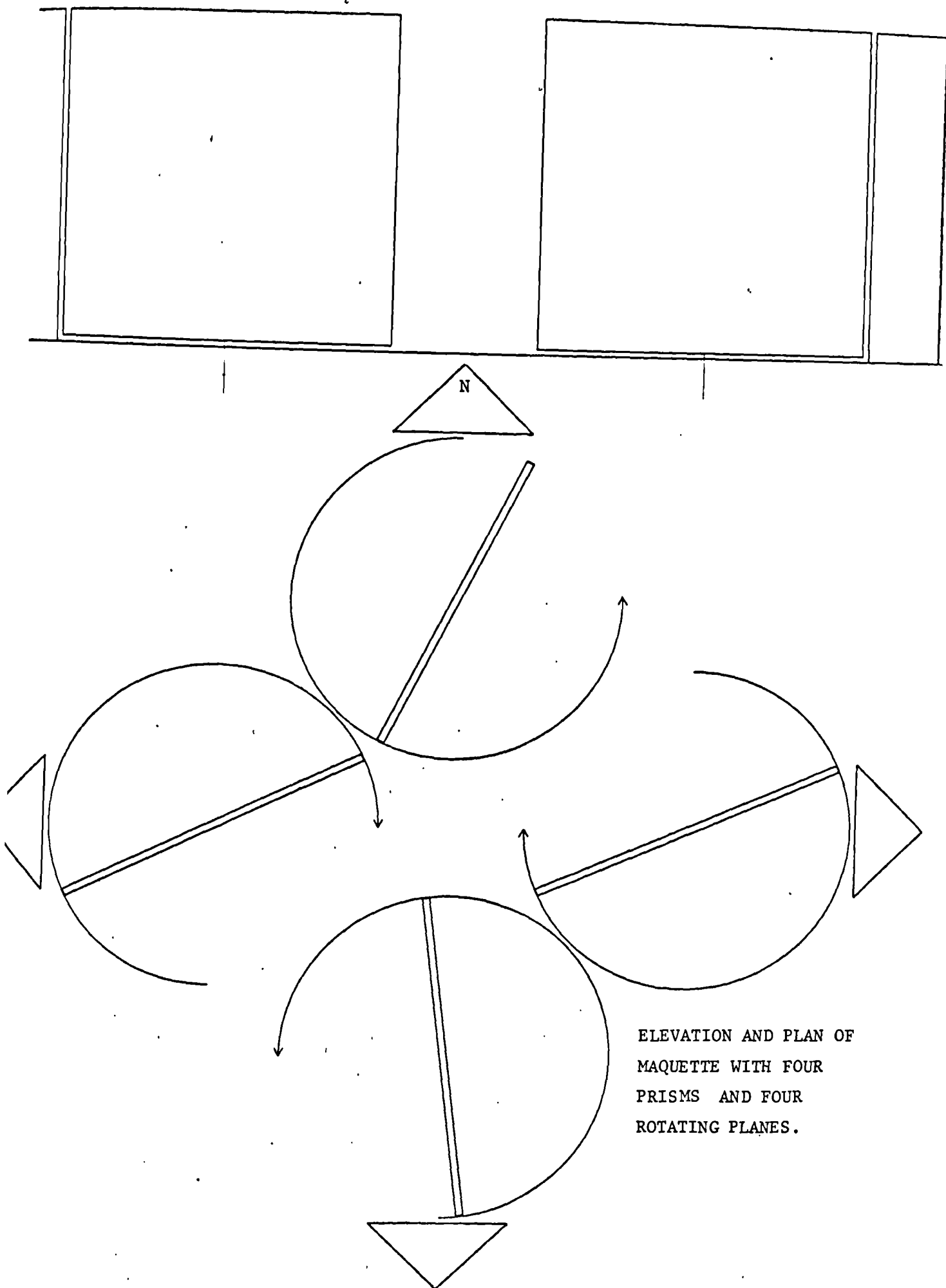


A - SPACE DISPLACED IN DIRECTION OF CENTER.

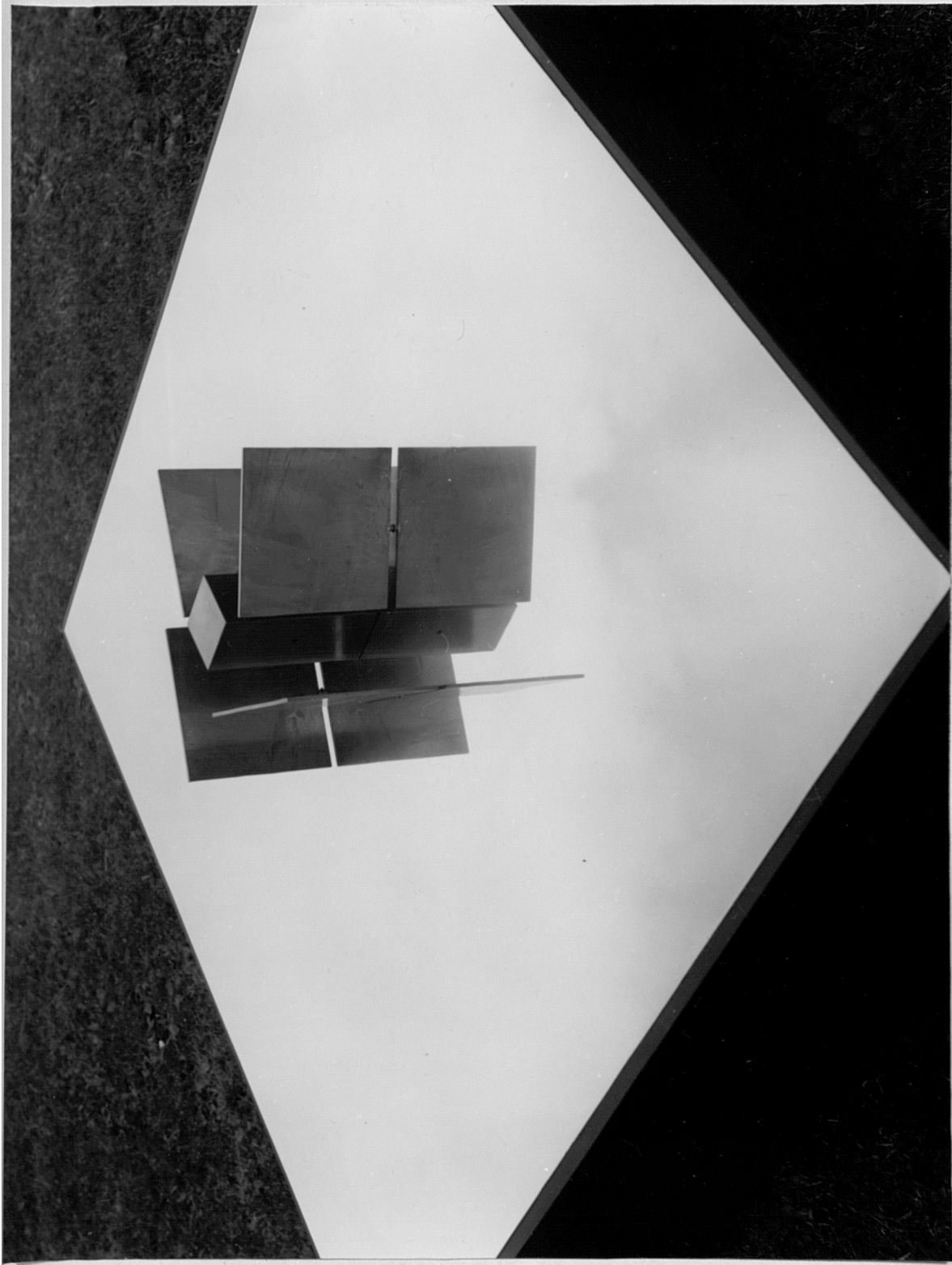
B - SPACE DISPLACED AWAY FROM THE CENTER.



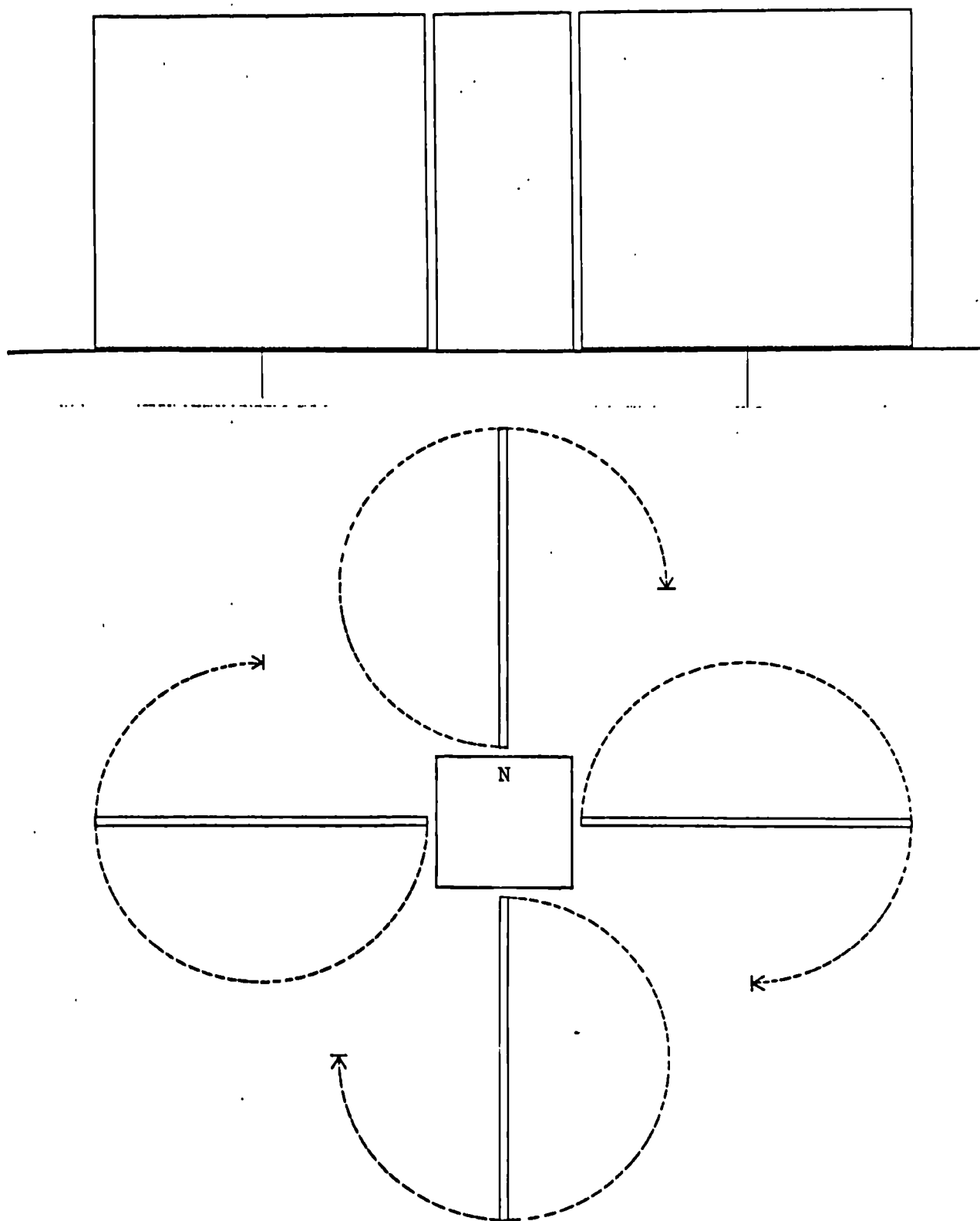
MAQUETTE, BASE 1' 10" x 1' 10".



ELEVATION AND PLAN OF
MAQUETTE WITH FOUR
PRISMS AND FOUR
ROTATING PLANES.



MAQUETTE, BASE 3' x 3'.



ELEVATION AND PLAN OF MAQUETTE WITH ONE SQUARE PRISM AND FOUR ROTATING PRISMS.

3.6.8. In both maquettes, the planes are each driven by Sanwa servo motors which are used in conjunction with the circuit described in section no. 10 of the appendix. With the use of the artificial sky, these motors are tuned to respond to a range of illumination from dull overcast (around sunset) to bright sunlight, (midsummer).

3.6.9. The maquettes have now been observed working out of doors over a variety of different climatic conditions. In the maquette where a triangular spatial volume is defined by four rectangular prisms, (see page 132) space does appear to be projected in the direction of the four rotating planes. (This is therefore consistent with requirement 'a' in paragraph 3.6.1.). By their movements, and the resulting changes in light patterns, the planes set up an infinite variety of contrasting spatial relationships within this volume. These continually punctuate and offset the main axes, which exist between the prisms and converge upon the centre of the rectangle.

3.6.10. In the other maquette, see page 134, (constructed in response to point 'b', paragraph 3.6.1.) space is displaced outwards and radiates along the main axes lines from each of the four faces of the central prism. This displacement is intermittently punctuated by the rotations of the surrounding planes, which set up an infinite number of changing spatial relationships and tensions between themselves, and the central prism.

3.6.11. From these observations it becomes obvious that the kinetic activity of these two maquettes represents a further extension of the cause and effect sequence outlined in paragraph 3.4.2. This is due to the integration of the speed of movement, with the degree of movement. The extreme sensitivity of the maquettes has resulted in a plane only having to rotate through a few degrees, for its reflections to change the light patterns in the other planes, and cause them to respond with more minor rotations. A chain reaction of this breadth was not foreseen during the planning stage of the maquettes, but it has heightened the existence of states of wholeness between

the sun, and the kinetic activity of the sculpture. These observations can be summarised as follows,-

- (a) Space/time relationships have been emphasised by the planes moving through varying degrees of rotation (from 0° - 270°) at different speeds.
- (b) The degree and speed of rotation of the planes, expresses an extremely sensitive and proportional response to fluctuations in sunlight which are observed in the reflective bases. For instance, minor fluctuations = a few degrees of rotation, usually at slow speeds; major fluctuations in sunlight = extensive rotation at higher speeds. This response is consistent with the requirement in paragraph 3.6.2., and it also represents an extension to the previous maquette, where only the degree of movement, not the speed, was proportional to fluctuations in sunlight (see paragraph 3.5.5. (b)).

CHAPTER 4

Conclusions

4.1.1. In our society the advances in the sciences have encouraged man to feel that he is living in a technological womb. This divorces him and renders him impervious to the influences of the natural environment. One result has been the disassociation of man from physiological and cosmic time; this has resulted in the adherence to technical-mechanical time which does no more than regulate the activities of the day (see paragraph 0.1.20.). As a consequence human action is no longer synchronised with the rising and setting of the sun, but with the movements of the hands of a clock. This has led to a perilous dichotomy which has divorced man from the essential rhythms through which there developed an organic wholeness between man and nature (see paragraph 0.1.8.).

4.1.2. Until the machine monopolised our attention, there was an accepted interaction between the artist's interest in the quality of experience, and the scientist's in quantifiable facts and statistics. As a result, art and science served the evolving consciousness of mankind in a total effort to establish a human world in the midst of an often hostile environment (see paragraph 0.1.8.). Through an interaction between art and technology, it has been the intention in the work discussed in this project to go some way in reawakening in the consciousness of modern man, the organic wholeness which did exist between man and nature. This has been attempted through the development of patterns of kinetic movement, which express the existence of states of wholeness between the sun, and devices with different technological bases.

4.1.3. The development of these patterns of movement emerged gradually through the identification and refinement of a series of cause and effect sequences. This involved investigations into many varied technical and aesthetic possibilities. It has been a characteristic of this project that a development which encountered limitations in one area, has experienced its extension in another. For instance, developments which commenced in the chemical area and

experienced limitations (see paragraph 1.1.23.) found their extension in the mechanical area (see paragraph 1.3.13.).

4.1.4. It wasⁱⁿ the latter area that the cause and effect sequence was first realised. It was achieved through the construction of a sculpture in which planes with reflective surfaces move in response to fluctuations in temperature. (see paragraph 1.3.16.) These reflective surfaces enable the spectator to observe fluctuations in sunlight (the cause) in the actual sculpture, before they are responded to by the movement of the planes (the effect). This cause and effect sequence emerges again in the second chapter of the thesis where a temperature sensitive piston rotates a mild steel plate (see paragraphs 2.3.12-13).

4.1.5. However, fluctuations in temperature are not always synonymous with changes in temperature; this has led to inconsistencies between the cause and the effect (see paragraph 3.0.5.). To alleviate the inconsistencies between the cause and effect, it was decided to confine further developments to the use of photoelectrical devices which respond only to the visible wavelengths of light. (see paragraph 3.0.7-8) It was also decided to investigate further the use of reflective surfaces as a means of identifying the cause (fluctuations in sunlight) and to juxtapose this with the effect (kinetic movement. See paragraphs 3.2.10.).

4.1.6. Two maquettes were constructed as a response to this decision. The first attempts to translate fluctuations in sunlight into a series of corresponding colour relationships (see paragraphs 3.1.1-7). In the second maquette, fluctuations in sunlight are transposed into actual movement through the rocking motions of a square Perspex plate (see paragraphs 3.2.1-11). In both maquettes a dichotomy became apparent between the technology on the one hand, and the movement on the other. For instance, in the second maquette the motor is activated by fluctuations in sunlight, regardless of whether it is driving the Perspex plate. The problem of kinetic movement as a direct response to sunlight is therefore solved cosmetically; it

is not the result of a genuine interaction with the technology. This is at variance with the aims of the project, it does little to dispel the current dichotomy which exists between man and nature.

4.1.7. The dichotomy between the technology and the movement was emphasised even more in the next maquette. This was based on the idea of kinetic movement celebrating midwinter and midsummer (see paragraphs 3.3.1-8). It became apparent during experiments with this maquette, that the most accurate method of enabling kinetic movement to celebrate midwinter and midsummer, would be to pre-programme the movement. But if pre-programming was introduced, then any genuine form of direct interaction between the technology and the sun would be eliminated; because kinetic movement could take place independently. Therefore, there is little chance of kinetic movement produced by this method expressing a state of wholeness between the sun and the technology. Unlike the seasonal rituals (see paragraph 0.1.4.) it is not a direct and observed response to the sun.

4.1.8. At this point I took the crucial decision that kinetic movement had to be the result of an authentic technical and aesthetic interaction (see paragraph 3.4.2.). This reduced the dichotomy between the technology and the movement and enabled

- (a) The kinetic movement to become a part of the technology..
- (b) The technology to become a part of the movement.

4.1.9. A maquette was constructed in which the degree of rotation of two planes is proportional to fluctuations in sunlight (see paragraphs 3.5.1-7). Movement therefore commences at sunrise and terminates at sunset. As the planes rotate they simultaneously undergo qualitative (aesthetic) and quantitative (technological) change. Qualitative change is connected with the way their form, and the perceptual nature of their surfaces are transformed by light and shadow patterns. But rotation also causes the photocells and

therefore the technology, to undergo quantitative change; the latter may cause or prevent additional movement.

4.1.10. Eventually, two further maquettes were constructed (see paragraphs 3.6.1-11). In these maquettes planes rotate at different speeds and intervals of movement which are proportional to fluctuations in sunlight. As the planes rotate their surfaces become perceptually unstable and indeterminate and continually redefine spaces. The planes have an intimacy in which they seek to readjust themselves to fluctuations in sunlight, as if they were some sort of primitive organism endeavouring to realise a symbiotic relationship with their creator, the sun. Prolonged observations suggest that these kinetic movements express states of wholeness between the technology and the sun, to a point which is almost indicative of the act of creation. This for me means that this research has led to a conclusion which both satisfies and exceeds my original aims.

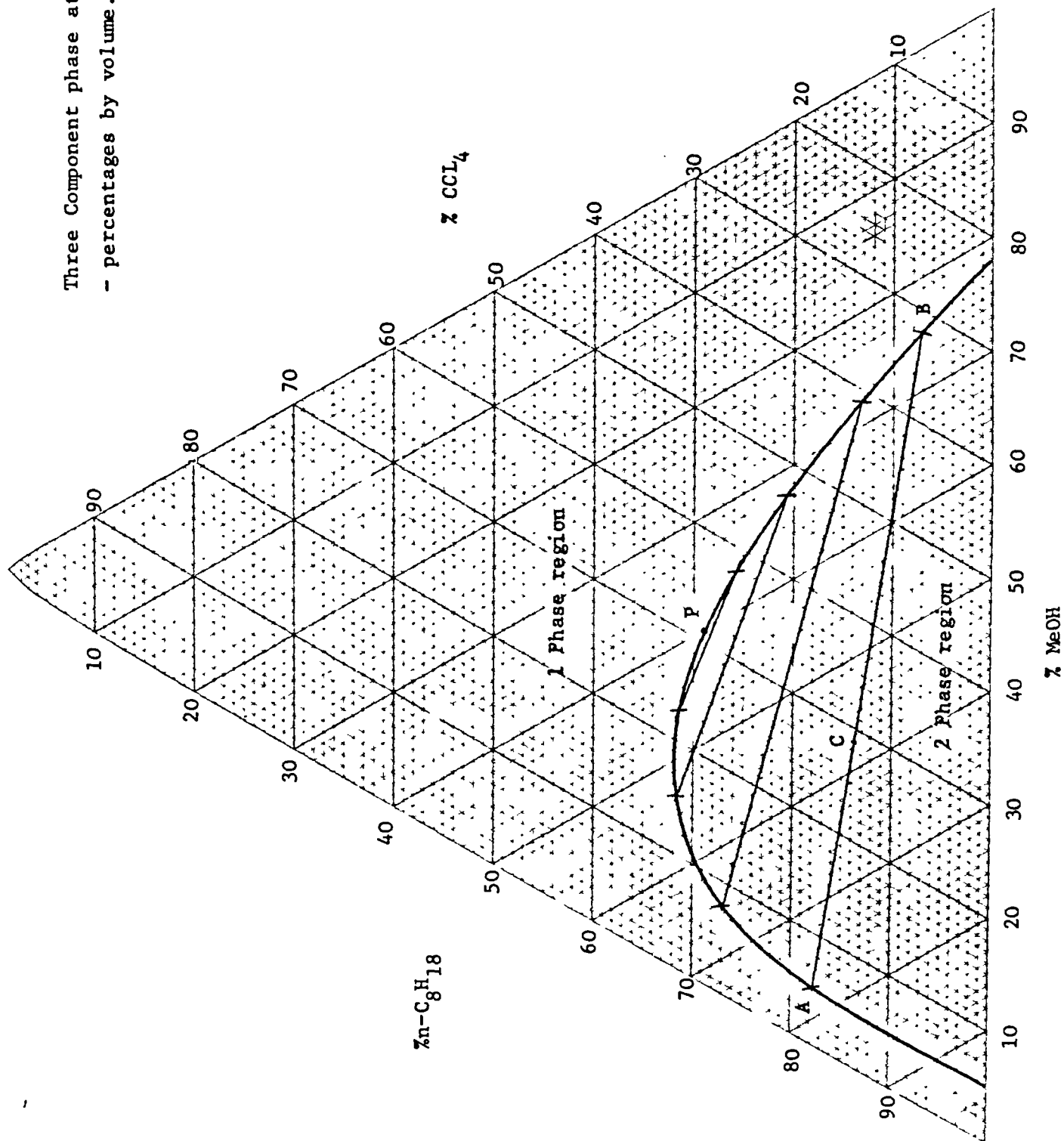
APPENDIX

1. In the three component phase diagram, the crosses at the ends of the 'tie-lines' represent the percentage compositions of the two phases. For example, the point A represents a phase consisting of 6% MeOH, 76% n-C₈H₁₈ at 18% CCL₄. This phase is in equilibrium with another denser phase, whose composition is given by the point B. The envelope at the ends of the tie-lines encloses the two phase region. A mixture whose overall composition lies within the envelope, e.g. C (30% MeOH, 14% CCL₄ and 56% n-C₈H₁₈) will separate into two phases, the compositions of which are given by the points at the extremities of the tie-line on which C lies. In this example, these are A and B. A mixture whose overall composition lies outside the envelope will be present as a single phase.

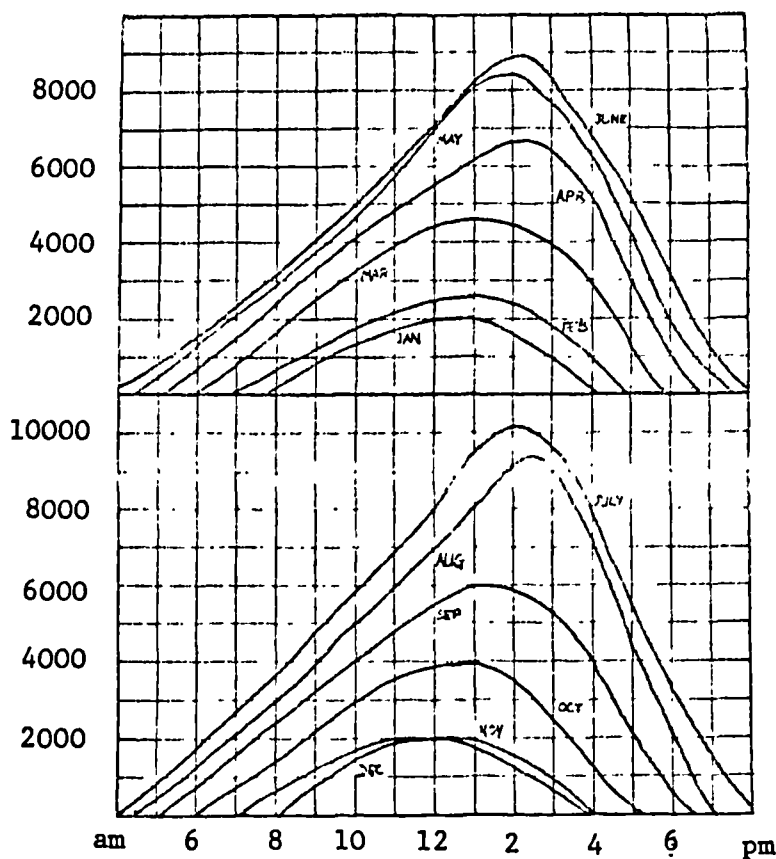
As the phases become richer in CCL₄, the tie-lines become shorter, eventually coalescing at a point, the Plait point P. Here the two phases are of identical composition and hence indistinguishable, and consequently a single phase results. Similar phase diagrams can be constructed at higher temperatures. These are characterised by a smaller two phase region, so that at a certain temperature a mixture at overall composition for example given by C, will cease to be within the two phase envelope and will instead, lie outside it. At this temperature, coalescence into a single phase will occur.

2. The graphs of illumination are to be found on pages 144, 145 and 146. These were based on the tables drawn up by J.W.T. Walsh, in The Science of Daylight, Macdonald, pp 29-35. Information relating to the sun's altitude and azimuth, which was used in conjunction with the graphs of illumination, was taken from, Sunpath Diagrams and Overlays (for lat. 52°N), published by the Building Research Station.

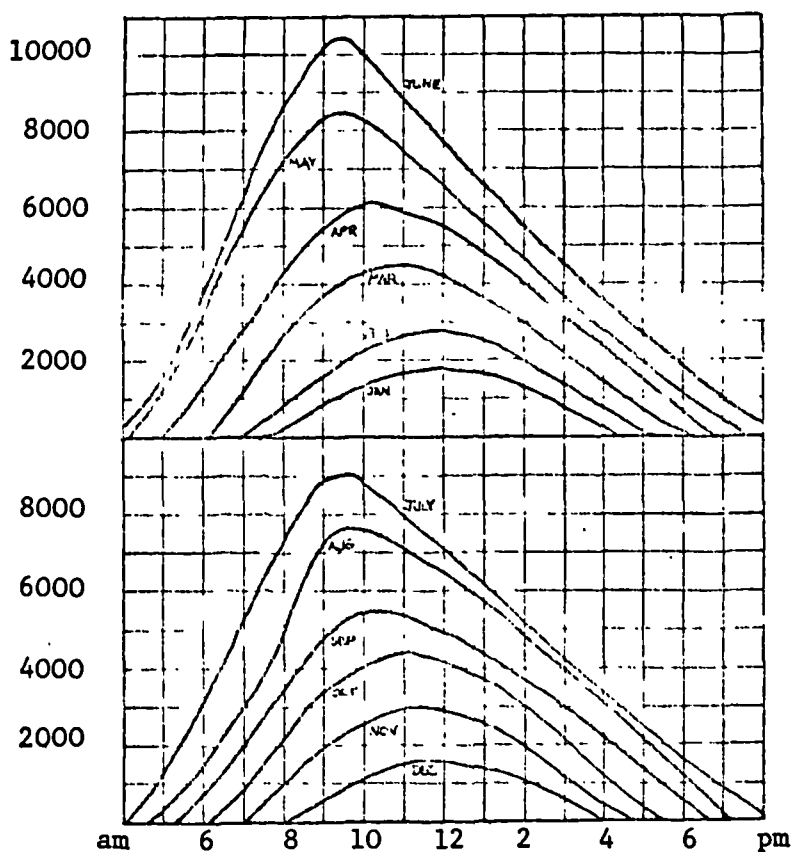
Three Component phase at 18°C
 - percentages by volume.



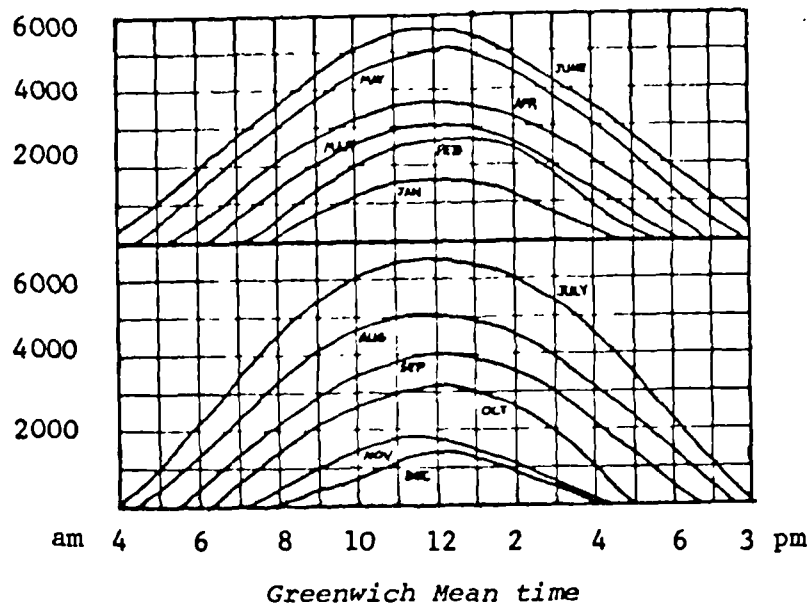
Illumination (lm m^{-2})



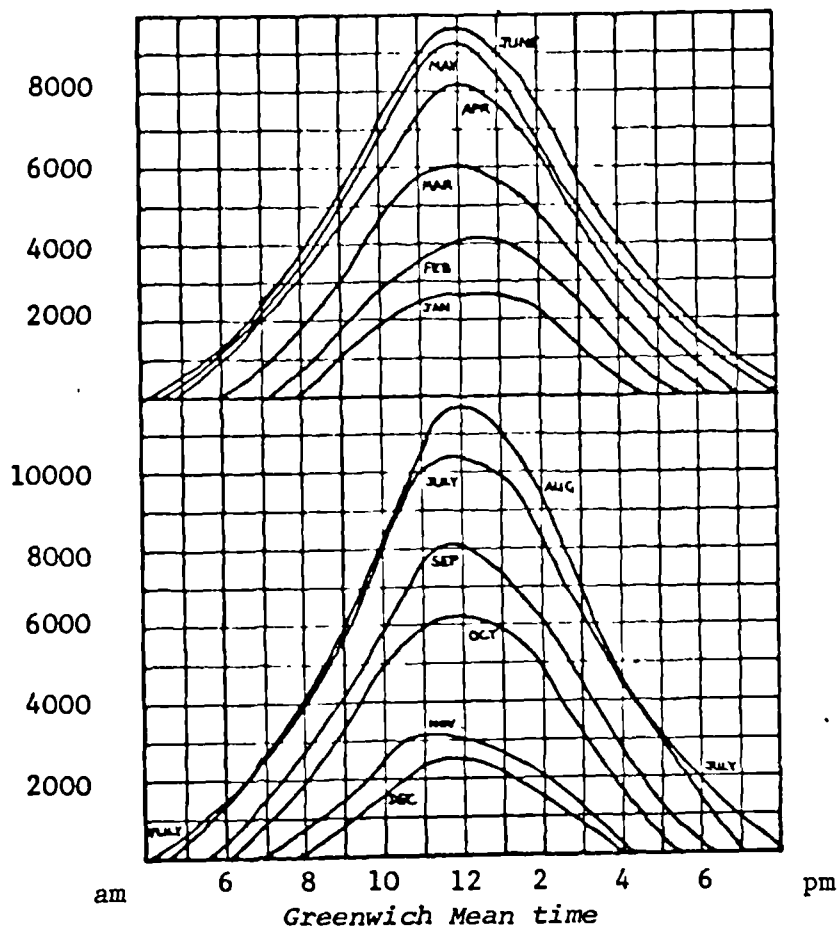
Greenwich Mean Time
Curves of illumination from West octant of sky



Greenwich Mean Time
Curves of illumination from east octant of sky

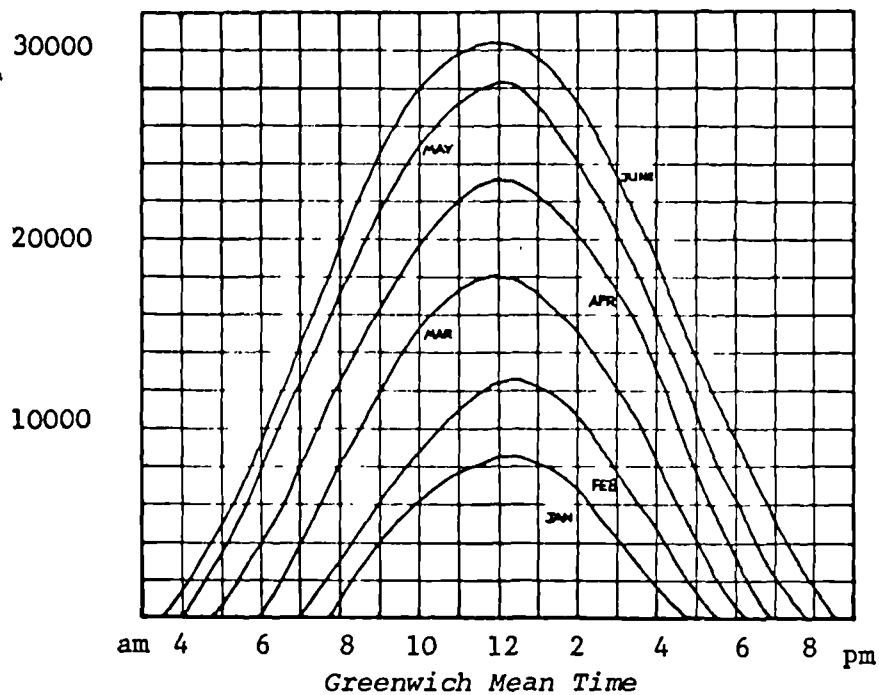


Curves of illumination from the north octant of sky

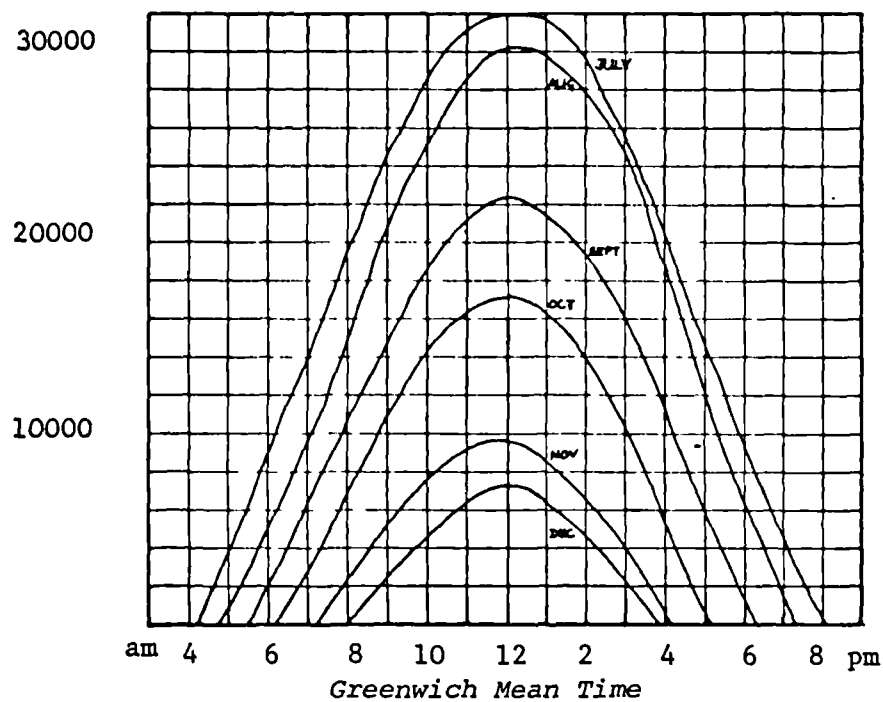


Curves of illumination from the south octant of sky

Illumination (lm m^{-2})



Curves of illumination from the whole sky (JAN-JUNE)



Curves of illumination from the whole sky (JULY - DEC)

3. A block diagram describing the sample and hold circuits and the accompanying components, is shown on page 148.
4. The diagram of the phase locked loop circuit (F.M. Circuit) is shown on page 149.
5. A graph of the piston's performance for 15th June 1976, is shown on page 150.
6. The circuit used in measuring the performance of the piston is shown on page 151.
7. The circuit diagram used in the construction of the piston servo mechanism is shown on page 152, with a photograph on page 153.
8. The maquette is constructed as follows. In the top of the obelisk is a $\frac{1}{8}$ " diameter aperture, covered with a $\frac{1}{16}$ " thick, clear Perspex sheet. Beneath this aperture is positioned an O.R.P. 12 photocell. Wires run from this photocell, through the centre of the obelisk, to the sample and hold circuit, in the base below.

At the centre of the plate of mirror finish stainless steel is a 3" square aperture, above which the obelisk is mounted. The aperture is filled with a $\frac{1}{4}$ " thick sheet of clear Perspex. Underneath is an identical sized sheet of clear Perspex with a sandblasted upper surface. A bolt passes through the centre of this Perspex square and into the centre of the obelisk. In so doing, the obelisk is secured to the upper face of the Perspex, and ultimately the stainless steel square.

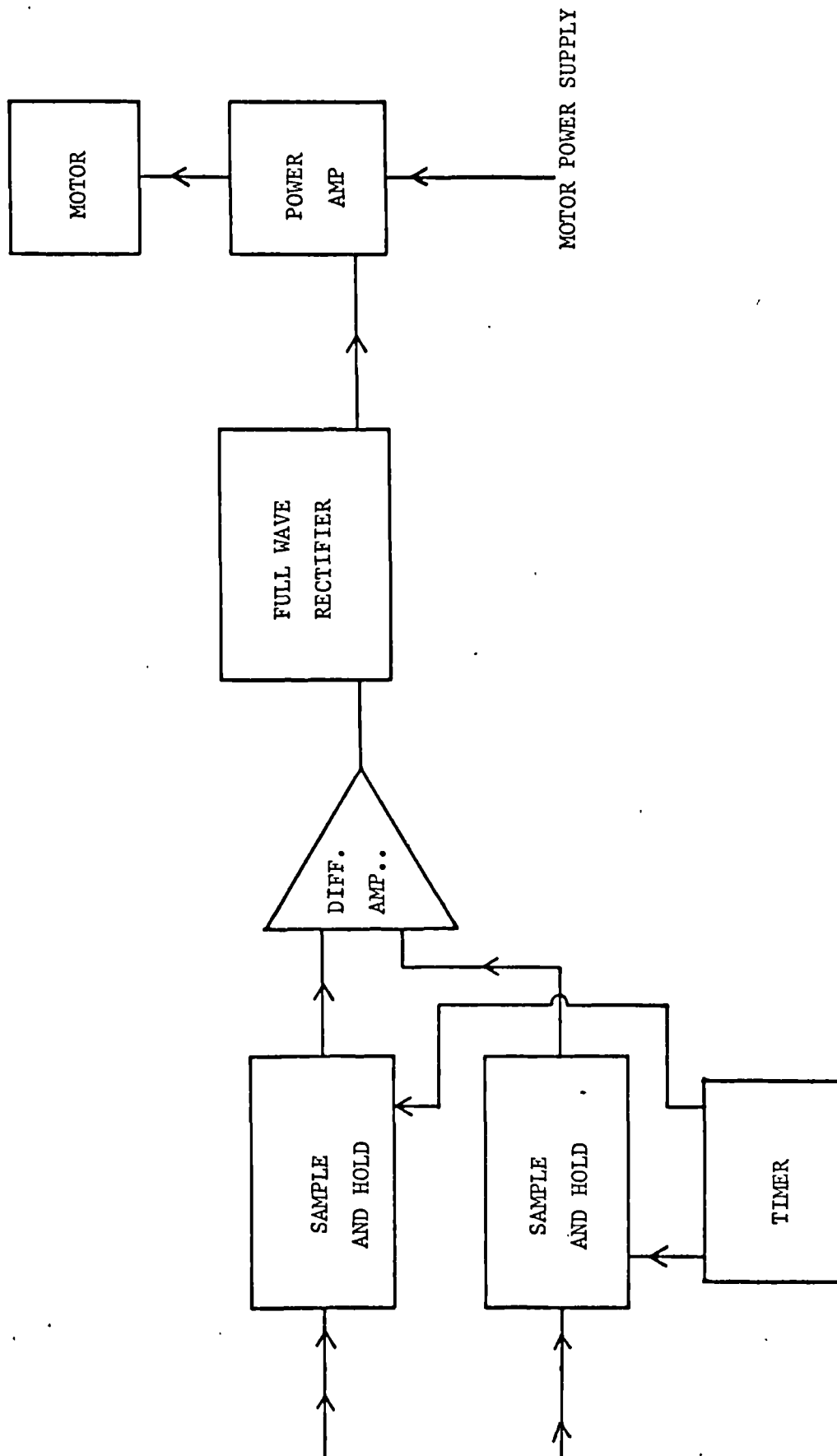
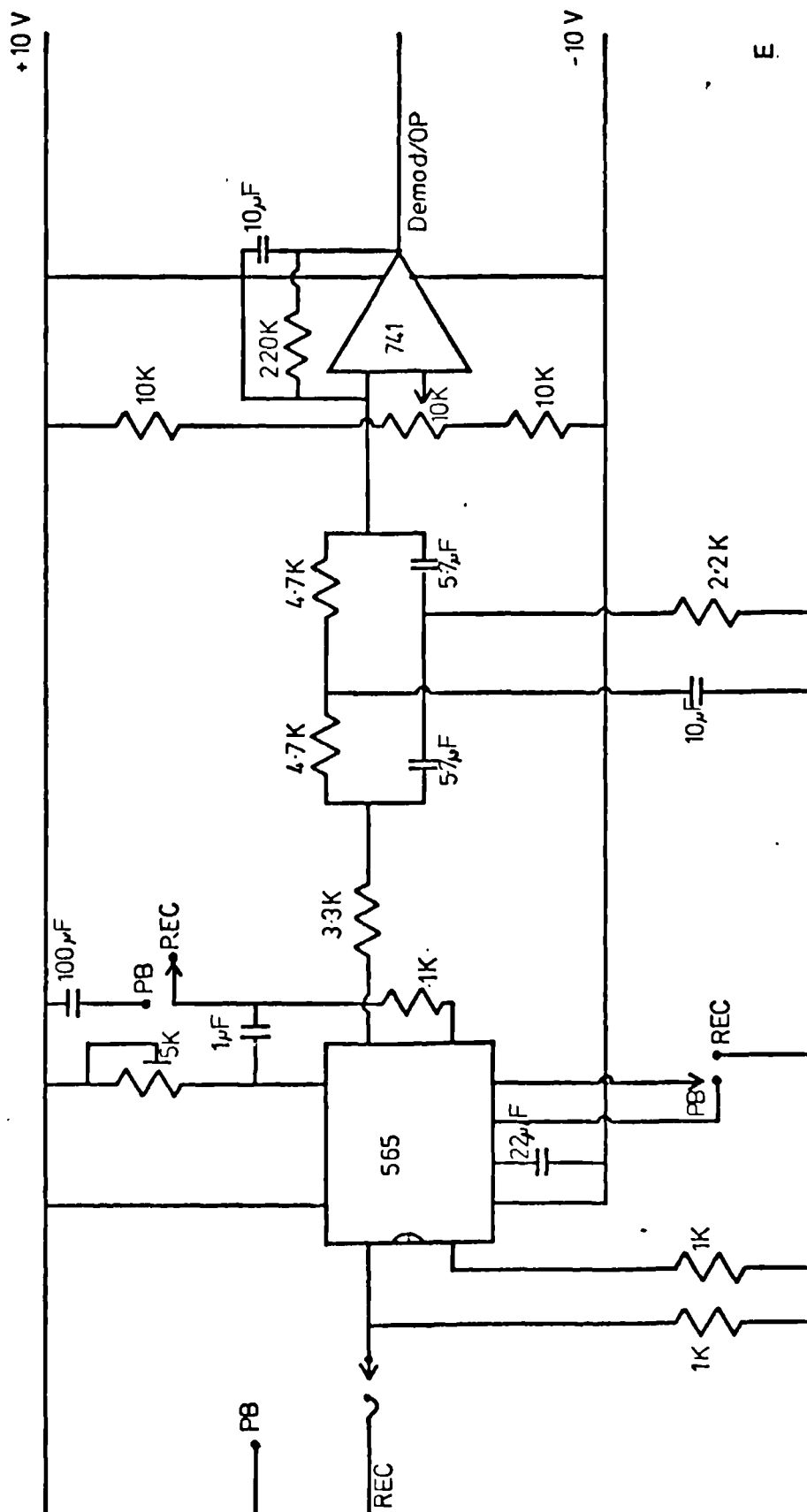


DIAGRAM OF SAMPLE AND HOLD CIRCUITS AND ACCOMPANYING COMPONENTS



PHASE LOCKED LOOP CIRCUIT

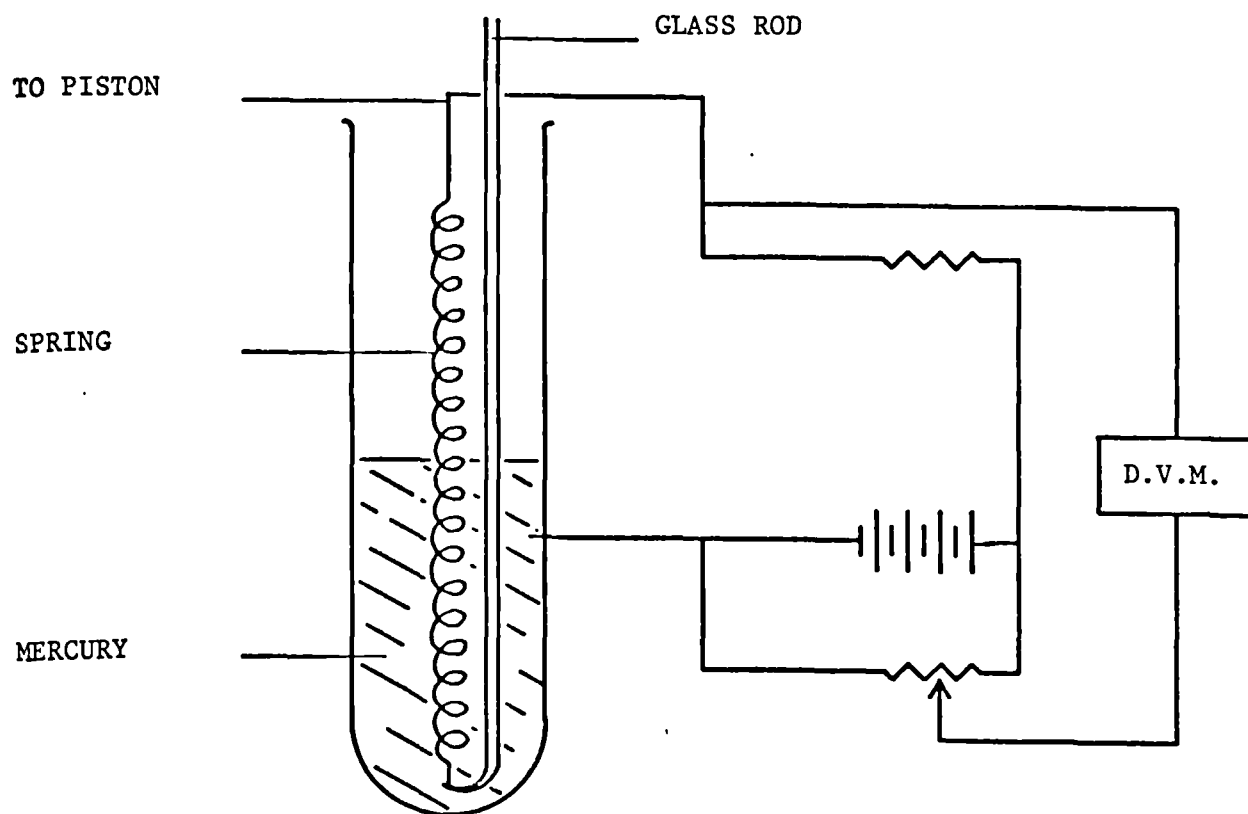
Greenwich Mean Time

4.20
4.40
5.00
5.20
5.40
6.00
6.20
6.40
7.00
7.20
7.40
8.00
8.20
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21.00
21.20

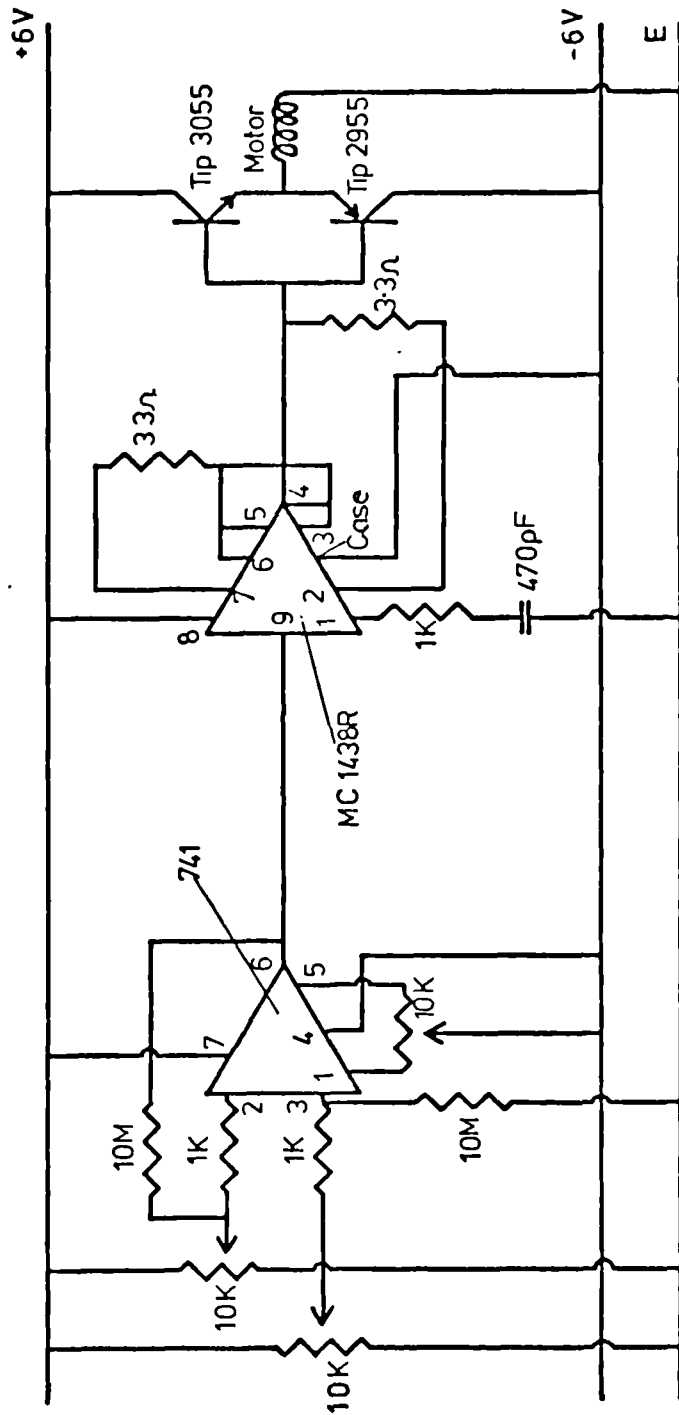
0mm, 10mm, 20mm, 30mm, 40mm, 50mm, 60mm, 70mm

displacement

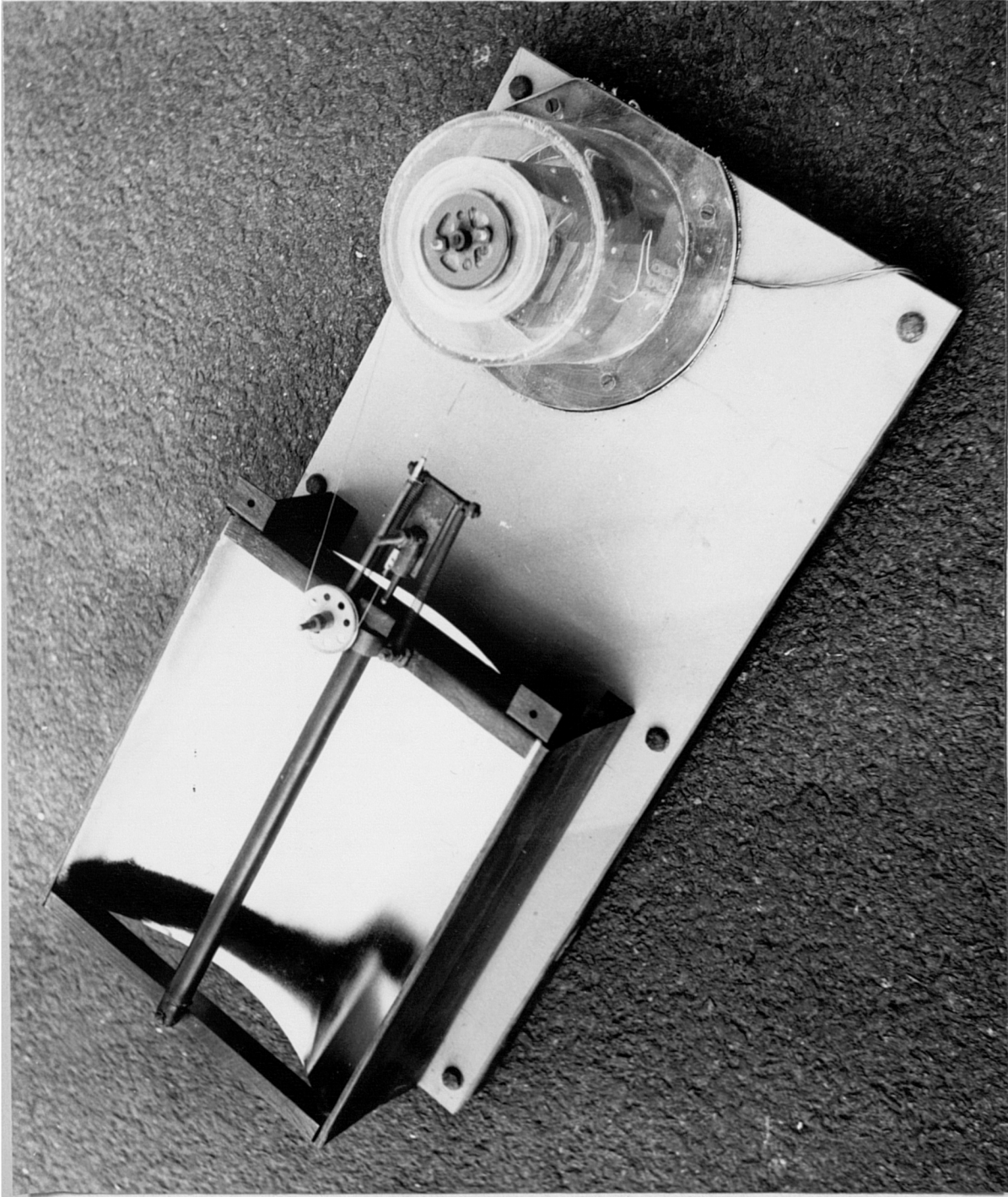
Performance of Piston on 15th June 1976



CIRCUIT FOR MEASURING PERFORMANCE OF PISTON



SERVO CIRCUIT FOR PISTON



SERVO MECHANISM.

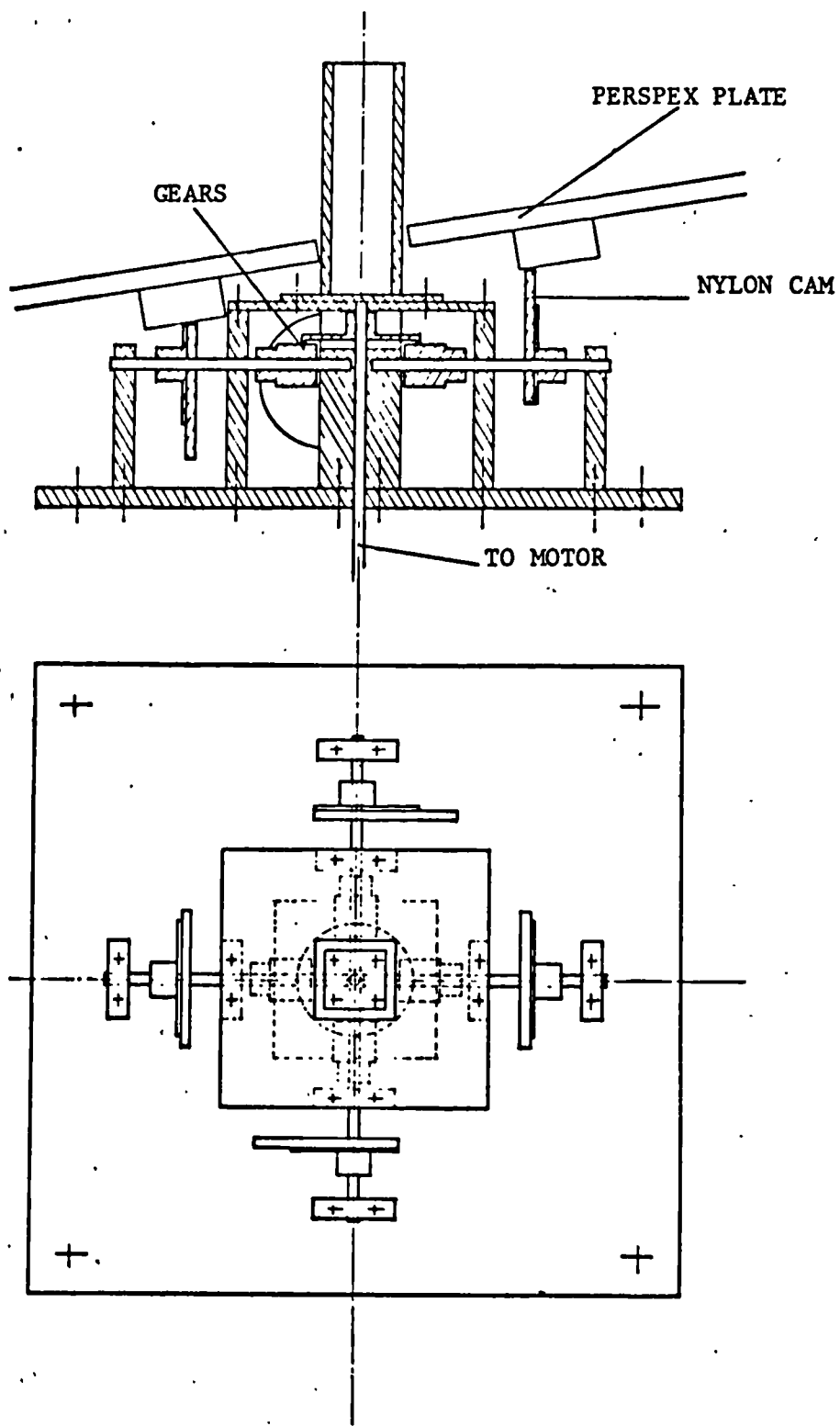
In the base, and directly beneath the Perspex aperture is a twelve volt electric light source. This shines directly through the Perspex and onto the four polished triangles at the base of the obelisk. It is cooled by an electric fan. In between the light source is a 1' diameter wheel, which is divided radially into six equal segments. Each of these segments accomodates a gelatine filter, the colours of which run through the spectrum in six stages, from red to blue.

The wheel of coloured filters is rotated by a continuously running six volt Meccano motor. This is connected to the wheel through a spring loaded slipping clutch. Stops are fixed at irregular intervals from the centre, on the underside of the wheel. These stops coincide with the divisions between the filters.

Beneath this wheel, but away from the light source, are positioned a row of six solenoids; each one corresponding to a stop on the wheel of filters. This enables any filter in the wheel to be selected by activating the appropriate solenoid.

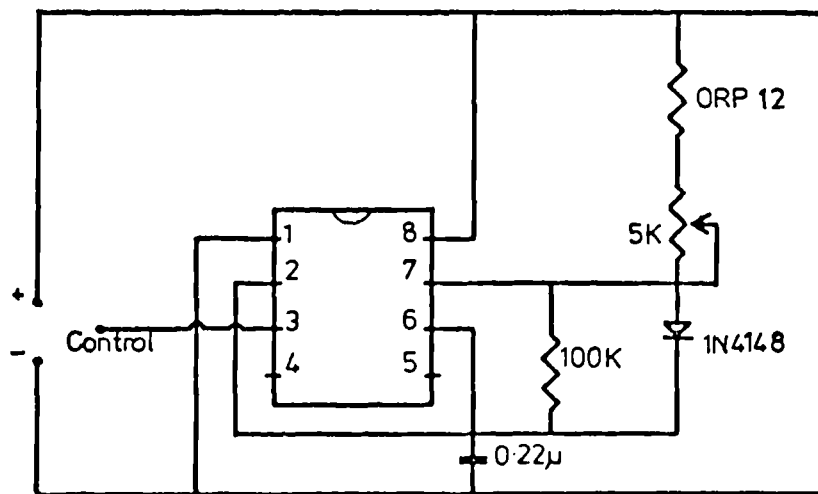
The colour which is projected onto the four reflective triangles at the base of the obelisk is selected according to thirty second fluctuations in illumination. For instance, no fluctuation in illumination causes blue (passive colour) to be projected onto the obelisk. Alternatively, severe fluctuations may cause red (active) to be projected.

9. An elevation, section and plan drawing of the rocking mechanism is shown on page 155. The gearing consists of Meccano parts which are modified to take 3/16" diameter spindles, the latter revolve in bronze bearings. The eccentric wheels are made of nylon.

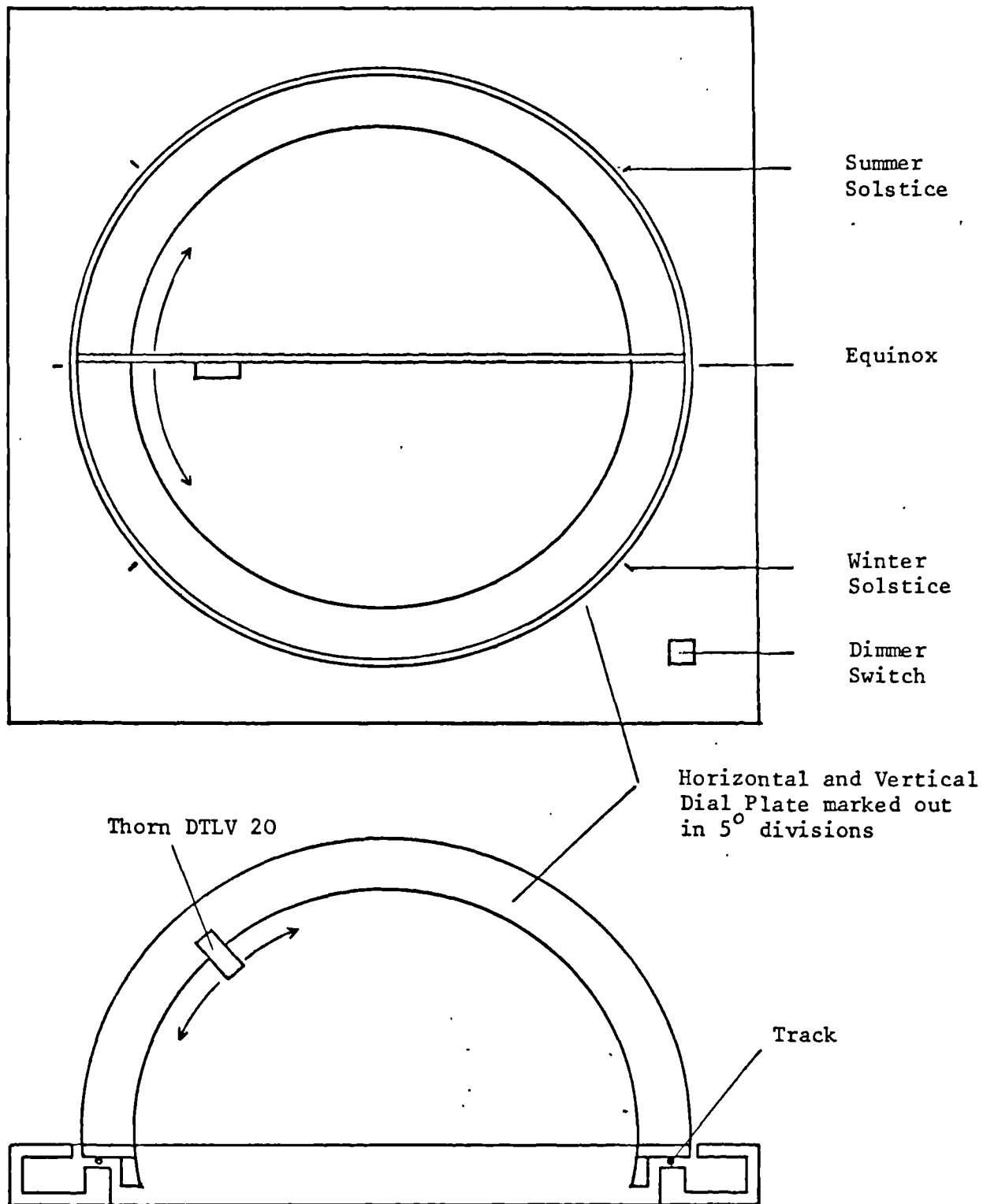


SECTION ELEVATION AND PLAN OF ROCKING MECHANISM.

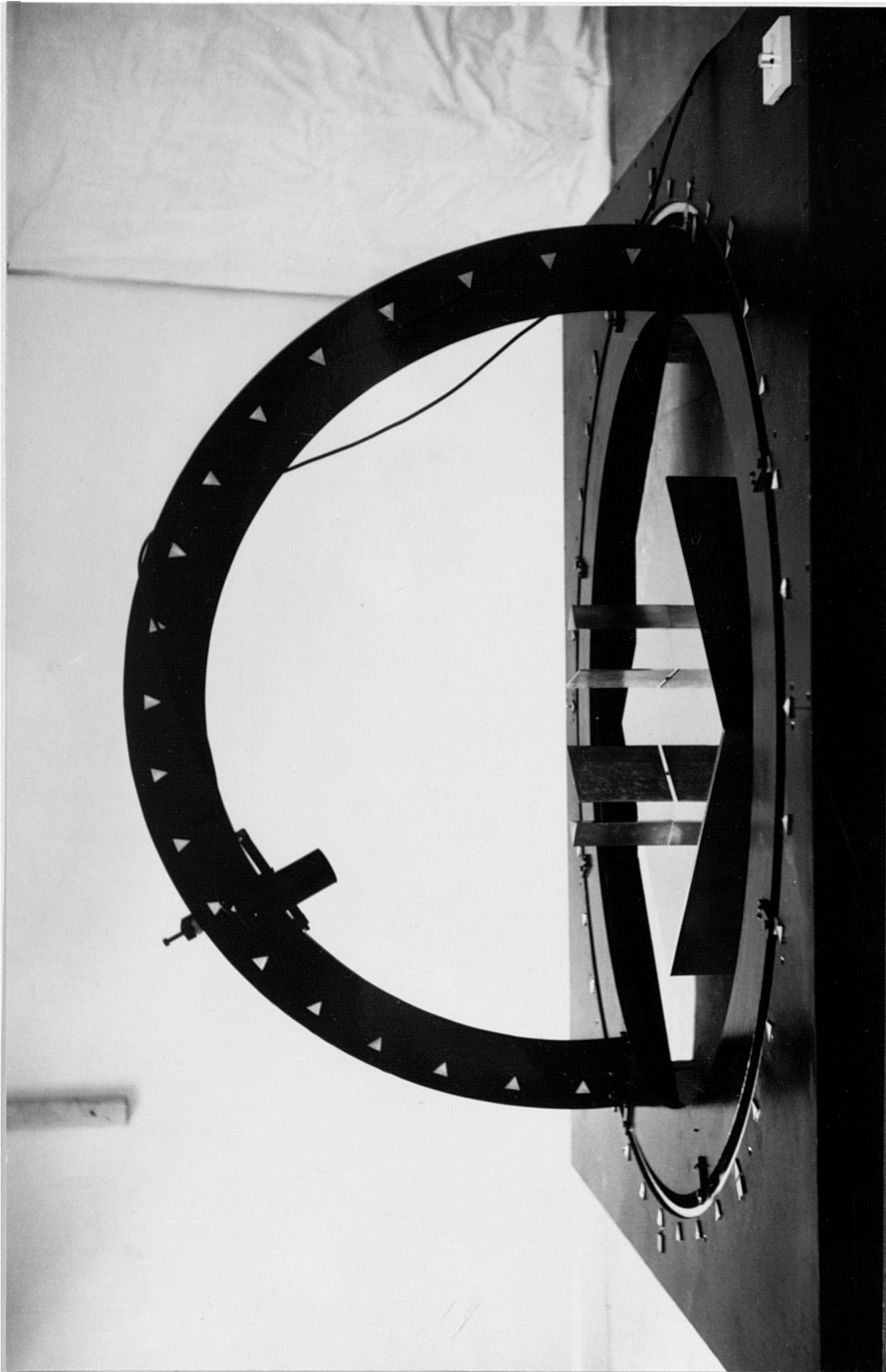
10. A Circuit diagram of the timing circuit for the I C mini servo SM-321, is shown on page 157. The control pulse applied to the servo is varied over the range of 0.6-5.0 mili seconds.
11. A plan and section elevation of the artificial sky and also a photograph, are shown on pages 158 and 159.
12. The polarity switching circuit for a Monoperm motor is shown on page 160.



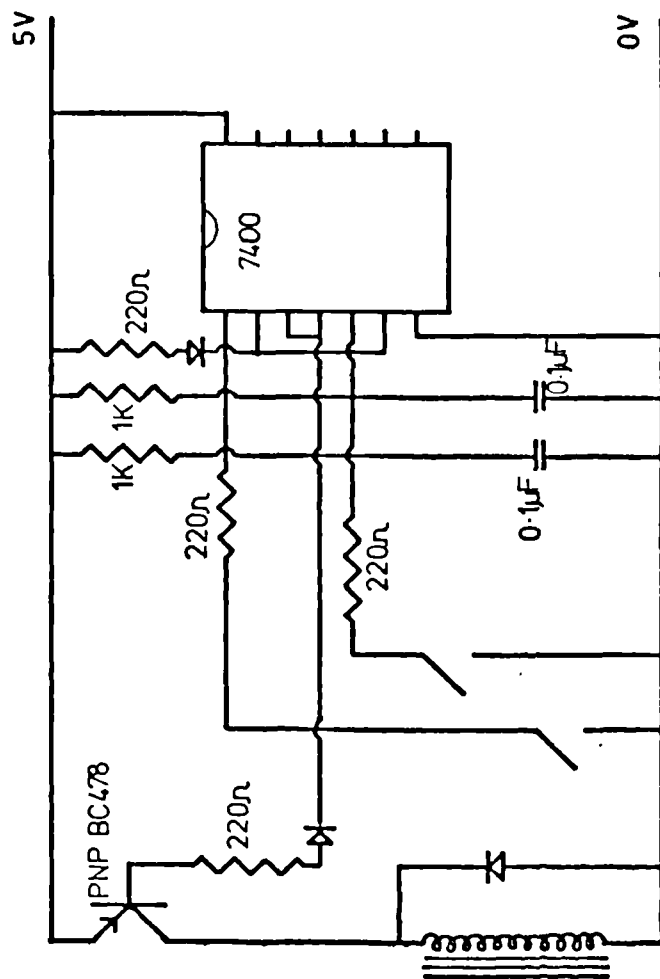
TIMING CIRCUIT FOR IC MINI SERVO SM-321.



PLAN AND ELEVATION OF ARTIFICIAL SKY. SCALE 1/12.



ARTIFICIAL SKY.



POLARITY SWITCHING CIRCUIT

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5. Ibid, p 99-118.
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